Control ENGINEERING

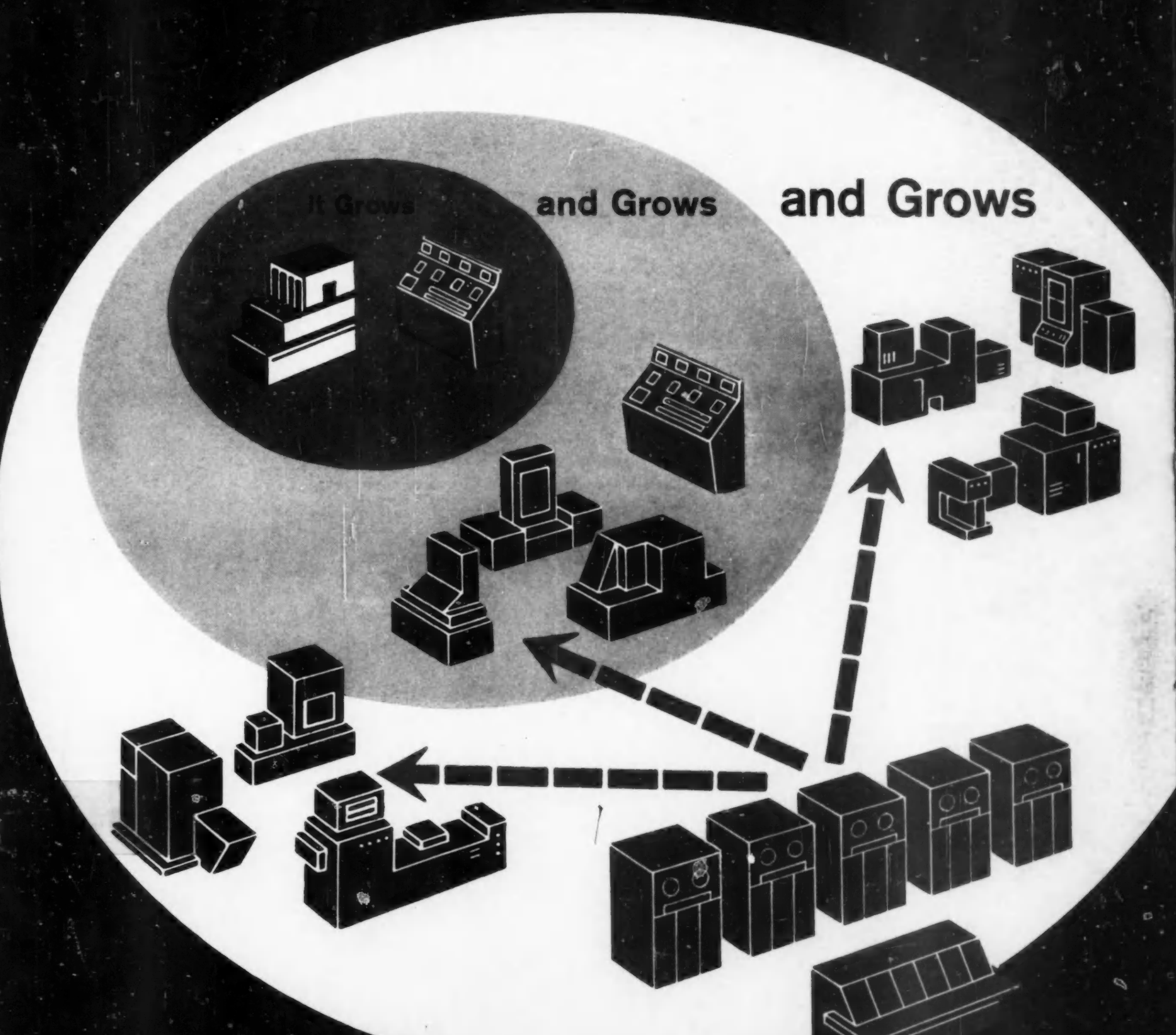
INSTRUMENTATION AND CONTROL SYSTEMS

A McGraw-Hill Publication

75 Cents

JANUARY 1960

Control Enters a New Decade



Control ENGINEERING

JANUARY 1960

VOL. 7 NO. 1

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

Continued on next page

PRINT ORDER THIS ISSUE 33,995

Published monthly by McGraw-Hill Publishing Co., Inc.; James H. McGraw (1860-1948), founder. PUBLICATION OFFICE, 99-129 North Broadway, Albany, N.Y. See panel below for directions regarding subscriptions or change of address. EXECUTIVE, EDITORIAL, CIRCULATION, and ADVERTISING OFFICES: McGraw-Hill Building, 330 West 42nd Street, New York 36, N.Y.

Officers of the McGraw-Hill Publishing Co., Inc.: Donald C. McGraw, President; Joseph A. Gerardi, Executive Vice President; L. Keith Goodrich, Vice President and Treasurer; John J. Cooke, Secretary. Officers of the Publications Division: Nelson L. Bond, President; Shelton Fisher, Senior Vice President; John R. Callaham, Vice President and Editorial Director; Joseph H. Allen, Vice President and Director of Advertising Sales; A. R. Venezian, Vice President and Circulation Coordinator.

Position and company connection must be indicated on subscription orders. Single copies, 75c, except \$2 for September issue. U.S. and Canada: one year, \$5. Foreign, one year, \$15. Second-class postage paid at Albany, N.Y. Printed in U.S.A. Title registered in U.S. Patent Office.

SUBSCRIPTIONS: Send subscription correspondence to Fulfillment Manager, CONTROL ENGINEERING, 330 West 42nd Street, New York 36, N. Y. For change of address, give old as well as new address, and include postal zone number. If possible, enclose address label from magazine. Please allow one month for change.

Postmaster: Please send form 3579 to Control Engineering, 330 W. 42nd St., New York 36, N. Y.

Continued on next page

you are looking at the best UNIVERSAL COUNTER-TIMER

Presenting the new CMC 226B

and here's the proof...

ENGINEERED FOR THE USER

CMC's new universal counter-timer is human engineered to eliminate costly "cockpit trouble." Take a look at the clean, functional lines.

And inside, this tastefully styled instrument uses modular circuitry to simplify maintenance and cut weight. Nine tubes have been eliminated, lowering power drain and operating temperature and increasing reliability. Weight is only 40 lbs.

TECHNICALLY SPEAKING

Direct reading, 0 to 1.2 mc. Time interval, 1 microsecond to 1 million seconds. Period, 0 microsecond to 1 million seconds. Stability of 2 parts in 10^7, with an option of 5 parts in 10^8. Sensitivity 0.1 volt rms.

Three input channels. Automatic decimal point indication. Reads directly in kilocycles, cycles, or microseconds.

Three independent, continuously adjustable trigger level controls for full rated sensitivity at any voltage level between −150 and +300 volts.

Oscilloscope marker signal to speed start and stop trigger level adjustment for TIM of complex waveforms; trigger level adjustment for amplitude discrimination in frequency and period measurement. Drives the CMC fast printer and most other types of printers and data handling equipment.

DO ALL THESE JOBS PRECISELY DO THEM EVERY TIME

Measure frequency, time interval, period, phase shift, frequency ratio, rpm, flow, velocity, and many other basic physical quantities.

NOW THE PRICE

$1100 fob Sylmar, California. Rack mount $10 extra. 220 kc Model 225C with similar specifications, $840 fob Sylmar.

WANT MORE DATA?

Your nearby CMC engineering representative will be happy to arrange a demonstration and provide you with complete technical information. Or you may write Department 081.

Computer-Measurements Company *A Division of Pacific Industries, Inc.*

12970 Bradley Avenue • Sylmar, California

Phone: EMpire 7-2161

22

SHOPTALK

Template reprinted by popular demand

In November's "Shoptalk" we asked how many readers would be interested in a reproduction on clear acetate of the template featured in that issue's "Data File" ("A Template for Designing Servo Compensators", p. 139). It didn't take long to find out. Response has been enthusiastic, and we've already gone to press, so that if you ordered one you should be getting it shortly if you haven't already. If you missed the first chance, but would like to receive this handy design tool, notice that it's been added to our reprint list (p. 175): transparent decibel vs phase angle template plus reprint of article for 75 cents.

Strange new components

Anyone who thinks there's no more room for inventiveness and imagination in the control field ought to sit where CtE's editors do for awhile. Not a month goes by but what someone contacts us to show off his unusual gadget. Many times "uniqueness" is their only outstanding characteristic, but there are always those few that show real potential (like "The Electrochemical Relay—A Remarkable New Switching Form", CtE, July '59, p. 121 and "The Strange New Ball Motor", p. 131 in this issue). The job of ferreting out these winners to present them to CtE's readers is one of the highlights of our editors' lives.

Control teacher writes and researches

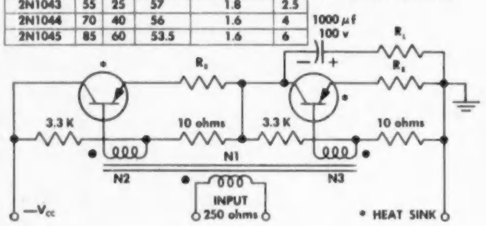
A prolific writer, George J. Thaler has already contributed more than his share to the literature of the control field, and this is only the beginning. Starting with *Servomechanism Analysis* (with Bob Brown of Notre Dame University, recently revised and to be republished under the name *Analysis and Design of Feedback Control Systems*), George is continuing with a nearly finished book on nonlinear control systems and has projected and partially written five more books: two on transients, one on the control aspects of electrical machinery, one on advanced linear servo theory, and one on sampled data systems. All this in addition to many technical papers and two CtE "Data Files" (the latest one "Analysis and Stabilization of Sampled Data Systems" on p. 123). A teacher at heart, George has taught control since he received his PhD in EE from Johns Hopkins in 1947. Now a full professor of EE at U. S. Naval Postgraduate School, he developed many servo courses and the servomechanism lab. On top of the writing load, he still finds time to carry on his own research and to play tennis three times a week in that fine Monterey weather.

Your best combination of I_{CBO}-R_{CS}-V-PLUS HIGH BETA ...TI germanium power transistors!

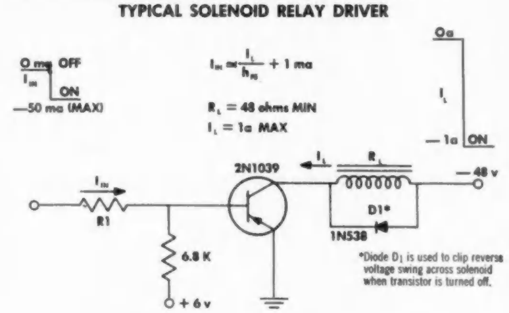
TYPICAL AUDIO AMPLIFIER 10 WATTS OUTPUT

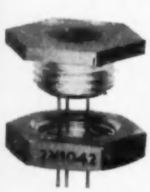
TRANSISTOR	V_{CC} volts	R_L ohms	Efficiency %	Distortion % at P_o=10w	R_E ohms
2N1042	35	10	58	2.7	1
2N1043	55	25	57	1.8	2.5
2N1044	70	40	56	1.6	4
2N1045	85	60	53.5	1.6	6

Transformer: N_1:N_2:N_3 = 1:1:1
To Minimize Cross-Over Distortion the Coils Should be Bifilar Wound.



TYPICAL SOLENOID RELAY DRIVER



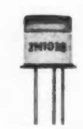


ACTUAL SIZE

20-w power transistors:

switching circuits • relay drivers • audio and pulse amplifiers

TI 2N1042 series alloy-junction transistors **guarantee** 20 w dissipation at 25°C with voltage ratings of −40, −60, −80, and −100 v. You get guaranteed 20-to-60 beta spread at −3 amps and low 0.16 ohm saturation resistance at the −3 amp maximum collector rating.



ACTUAL SIZE

1.25-w power transistors:

medium speed switching circuits • relay drivers • low-power audio and pulse amplifiers

TI 2N1038 series alloy-junction transistors **guarantee** 1.25 w dissipation in moving free air at 25°C with voltage ratings of −40, −60, −80, and −100 v. **Guaranteed** 20-to-60 beta spread at −1 amp and low 0.2 ohm saturation resistance assure reliable performance.

TI GERMANIUM POWER TRANSISTOR CHARACTERISTICS AT 25°C

Type	Dissipation at 25°C Watts	Max Collector Voltage Volts	Max Collector Current Amps	h_{FE} min	h_{FE} max	Collector Reverse Current I_{CO} max	Typical Saturation Resistance R_{CS} Ohms
2N456	50	−40	−5	10 @ −5a	50	−2ma @ −40v	0.048
2N457	50	−60	−5	10 @ −5a	50	−2ma @ −60v	0.048
2N458	50	−80	−5	10 @ −5a	50	−2ma @ −80v	0.048
2N511	80	−40	−10	10 @ −10a	30	−2ma @ −20v	0.025
2N511A	80	−60	−10	10 @ −10a	30	−2ma @ −30v	0.025
2N511B	80	−80	−10	10 @ −10a	30	−2ma @ −40v	0.025
2N512	80	−40	−15	10 @ −15a	30	−2ma @ −20v	0.025
2N512A	80	−60	−15	10 @ −15a	30	−2ma @ −30v	0.025
2N512B	80	−80	−15	10 @ −15a	30	−2ma @ −40v	0.025
2N513	80	−40	−20	10 @ −20a	30	−2ma @ −20v	0.025
2N513A	80	−60	−20	10 @ −20a	30	−2ma @ −30v	0.025
2N513B	80	−80	−20	10 @ −20a	30	−2ma @ −40v	0.025
2N514	80	−40	−25	10 @ −25a	30	−2ma @ −20v	0.025
2N514A	80	−60	−25	10 @ −25a	30	−2ma @ −30v	0.025
2N514B	80	−80	−25	10 @ −25a	30	−2ma @ −40v	0.025
2N1021	50	−100	−5	10 @ −5a	30	−2ma @ −100v	0.08
2N1022	50	−120	−5	10 @ −5a	30	−2ma @ −120v	0.08
2N1038	1.25	−40	−1	20 @ −1a	60	−125µa @ −20v	0.2
2N1039	1.25	−60	−1	20 @ −1a	60	−125µa @ −30v	0.2
2N1040	1.25	−80	−1	20 @ −1a	60	−125µa @ −40v	0.2
2N1041	1.25	−100	−1	20 @ −1a	60	−125µa @ −50v	0.2
2N1042	20	−40	−3	20 @ −3a	60	−125µa @ −20v	0.16
2N1043	20	−60	−3	20 @ −3a	60	−125µa @ −30v	0.16
2N1044	20	−80	−3	20 @ −3a	60	−125µa @ −40v	0.16
2N1045	20	−100	−3	20 @ −3a	60	−125µa @ −50v	0.16
2N1046	35	−80	−3	20 @ −3a	160	−1ma @ −40v	0.9

germanium and silicon transistors
silicon diodes and rectifiers
tan-TI-cap solid tantalum capacitors
precision carbon film resistors
sensistor silicon resistors

TEXAS

FEEDBACK

READERS' CONTROL WORKSHOP

A reader in England suggests a cheaper way to simulate stiction than C. L. Dunsmore's ("Computer Analogs for Common Linearities", Oct. '59, pp. 109-111). We'd like to hear from anyone who builds the new circuit. Ed.

To the Editor—

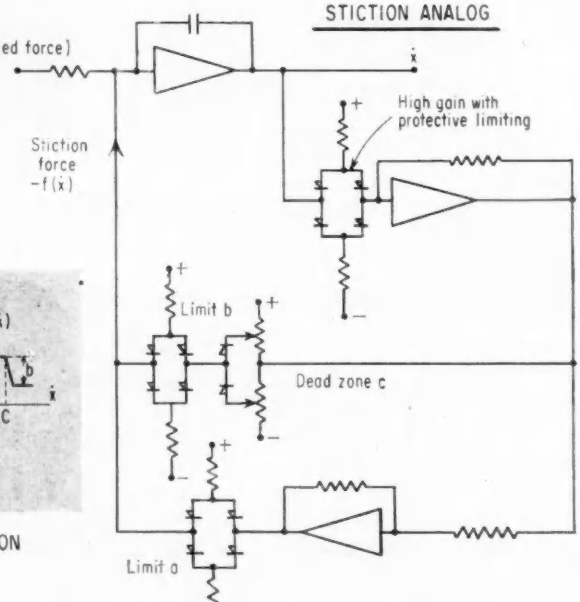
I should like to take up a small point with Mr. C. L. Dunsmore, author of "Computer Analogs for Common Nonlinearities" in the October '59 issue. May I suggest an alternative to his Figure 10, Stiction (Breakaway Friction) Analog on page 111. In that diagram, $f(\dot{x})$ apparently represents the required force function to represent stiction, which will surely be fed back into the integrator; thus to produce a single input $\ddot{x}$ to the integrator, a summing amplifier must precede it. This condition is suggested by the sign of $f(\dot{x})$ which is generated. If this is so, then in many instances a further sign reversing amplifier will be required as well. An equipment hog indeed!

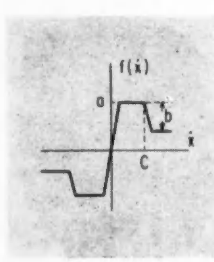
I have produced a simple simulation of stiction which may be of interest. See my figure. It does not perform identically to Mr. Dunsmore's in the instance where velocity approaches very close to zero and subsequently increases in its original direction. The distinction is academic in view of the present state of knowledge about actual friction as velocity decreases toward zero. Performance has been convincing and has produced results which, making due allowance for uncertainty of physical constants, properly represent mechanical conditions.

The operation of the circuit should be fairly easily understood from my figure, once it is pointed out that the three four-diode bridges are used as low resistance current limiters. One of these is used solely to prevent amplifier overloading.

R. S. Taunton
The Staveley Research Dept.
Bedford, England

STICTION ANALOG





STICTION

(Continued on p. 12)

an improved

VICKERS.
SERVO VALVE

...yet priced

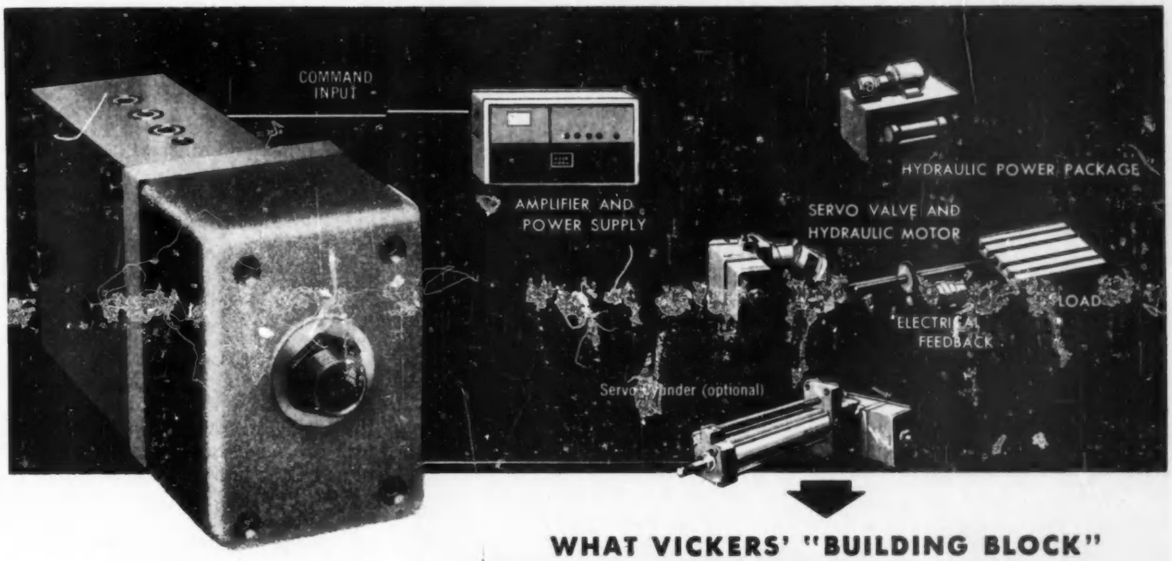
20% below

previous models

FOR PRECISE CONTROL OF OIL FLOW IN INDUSTRIAL, MILITARY AND MARINE HYDRAULIC SYSTEMS WHERE HIGH RESPONSE, ACCURACY, SIMPLICITY, RUGGEDNESS AND DEPENDABILITY ARE ESSENTIAL

Input signal to this improved Vickers electro-hydraulic servo valve can originate from a simple calibrated potentiometer or a sophisticated magnetic or punched tape reader system—yet the result is always extremely precise hydraulic flow proportional to the electrical command. This valve can be applied to a broad array of machine tools, process equipment and ordnance applications and is compatible with the wide range of command input methods commercially available.

There are only four moving parts in the two-stage, spool assembly of the Vickers servo valves, thus providing a simple, contaminant tolerant, exceptionally reliable operation. Get details by writing for Bulletin 59-74.



Available in models for flows to *37 gpm* and suitable for operation at pressures to *3000 psi* with a choice of mountings.

WHAT VICKERS' "BUILDING BLOCK" CONCEPT MEANS TO YOU

These pre-engineered electro-hydraulic servo systems offer positional accuracies of $\pm$.0015-inch; and down to $\pm$.0005-*inch* using the same standard components but with additional "trim." Your cost for Vickers "Building Block" systems is far below that normally associated with this degree of accuracy and response. These systems are specifically designed for heavy duty, industrial use.

Plug-in elements make trouble shooting and maintenance easy. Vickers' worldwide service organization insures unmatched backup for your personnel when required.

Why not contact the Vickers office near you today for more facts?

TYPICAL APPLICATIONS

Controlling velocity in processing applications • controlling position of machine tool slides and tables • programmed control of work handling and machine sequencing.

VICKERS INCORPORATED
DIVISION OF SPERRY RAND CORPORATION
Machinery Hydraulics Division
ADMINISTRATIVE and ENGINEERING CENTER
Department 1606 • Detroit 32, Michigan

Application Engineering Offices: ATLANTA • CHICAGO AREA (Bensenville)* CINCINNATI • CLEVELAND • DETROIT* • GRAND RAPIDS • HOUSTON INDIANAPOLIS • LOS ANGELES AREA (El Segundo) • MILWAUKEE NEW YORK AREA (Springfield, N.J.)* • PHILADELPHIA AREA (Media) PITTSBURGH AREA (Mt. Lebanon) • ROCHESTER • ROCKFORD • SAN FRANCISCO AREA (Berkeley) • SEATTLE • ST. LOUIS • WORCESTER
Factories also in: Australia, England, Japan and Germany
In Canada: Vickers-Sperry of Canada, Ltd., Toronto,* Montreal and Vancouver
Field Service Headquarters Underlined. Whse. Stock & Repair Branches*.

8479

ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921

FEEDBACK

Here's how to find a ship all at sea.

To the Editor—

In the "What's New" section of the October '59 issue you carried a very interesting article on transmission of missile test data along the Atlantic Missile Range. We noticed one point, however, in which either Mr. Dederer or your editors erred. This error concerned the positioning of ships along the range. Your article stated that ship positions will be determined by the Loran system, whereas the system to be used is Lorac.

The difference in the two systems is more than just the name. While Loran has sufficient accuracy for ship navigation, it falls far short of the requirements for pinpoint positioning as required on the missile range. Lorac, on the other hand, provides positioning information on the order of 50 feet in 50 miles.

Stanley W. Wilcox
Seiscor Manufacturing Co.
Tulsa, Okla.

Positioning information for the USS *Observation Island*, test vessel for the Polaris Missile Project, is being provided by the Lorac radio-positioning system. The Polaris project is the latest application of the pinpoint positioning system developed and manufactured by Seiscor, a division of Seismograph Service Corporation, Tulsa, Okla. The system is used to provide instantaneous position information for the test vehicle during countdown so the highly critical tracking radar can pick up the missile as soon as it appears on the horizon.—Ed.

Wants magnetic inks and readers.

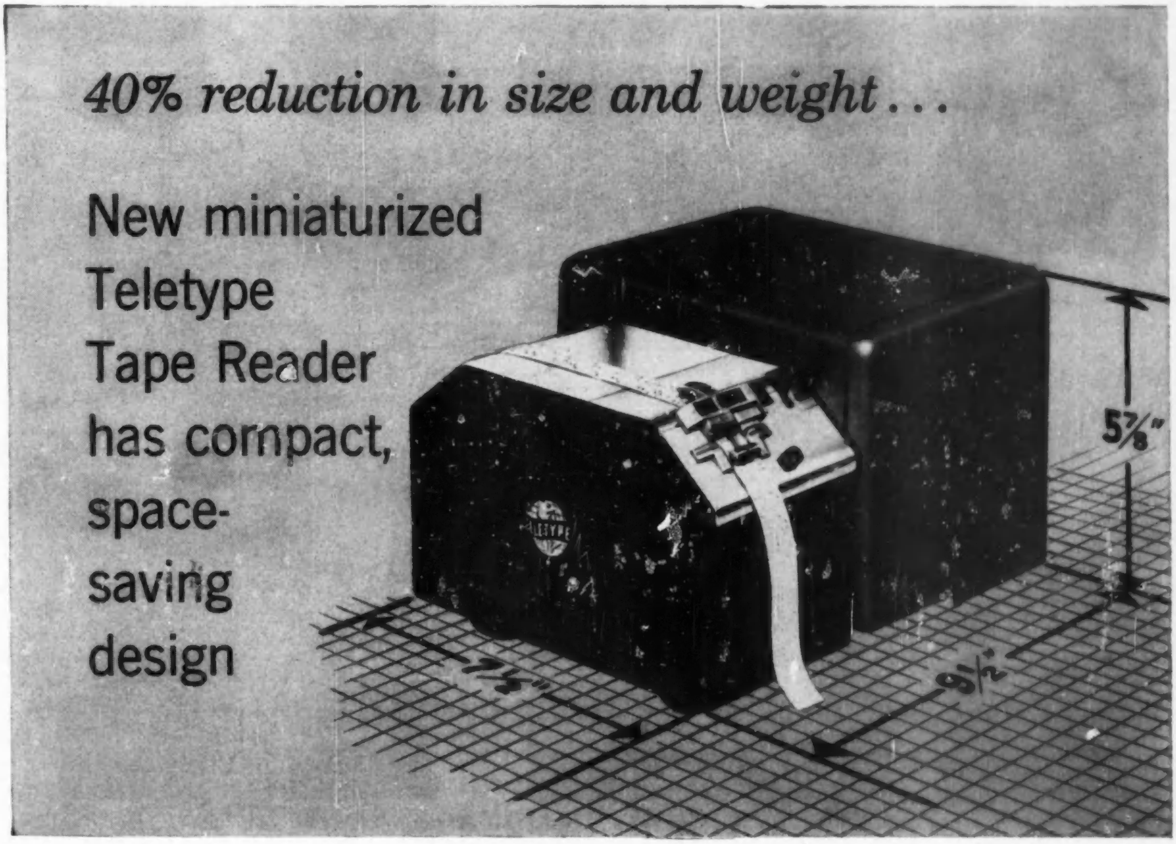
To the Editor—

A request for a little assistance. If available, could we have a reprint (or tear copy) of "How to Reduce Interaction Between Control Loops" by J. E. Valstar, June '59 issue?

Second, we noted the article on check processing in the July '58 issue. We would like to get as much data on this subject as possible—inks and who makes them, readers and their characteristics, cost.

W. F. Davis
Consultants
Hightstown, N. J.

Valstar reprint on the way. For full information on inks and equipment used in check processing, check with the authors. You might begin with K. R. Eldridge, Stanford Research Institute, Menlo Park, Calif. Ed.



Here is a new tape reader set from Teletype Corporation—the Model 28 miniaturized LXD. It features a 40% reduction in size and weight. This new space-saver set is completely compatible with other Teletype communications equipment. It features facilities for sequential (serial) transmission, with optional contacts available for multi-wire output, and it is designed to read either chadless or fully perforated tape.

The Model 28 miniaturized LXD tape reader is made, as is all Teletype equipment, for round-the-clock, day-in, day-out service with minimum maintenance. The unit is equipped with an all-metal clutch that requires lubrication only once or twice a year, and operates with precision accuracy for continuous or intermittent transmission.

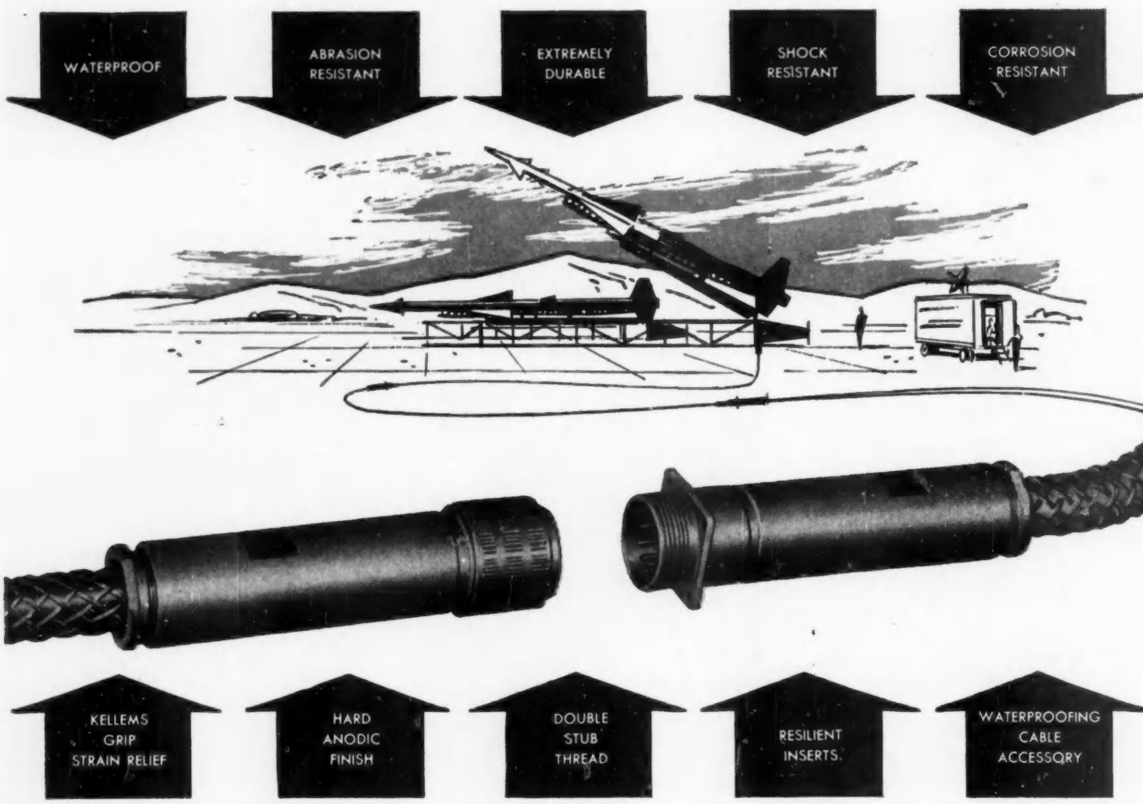
New Brochure **A 4-page brochure on the new Teletype miniaturized LXD tape reader is available upon request. Write to Teletype Corporation, Dept. 26A, 4100 Fullerton Ave., Chicago 39, Ill.**

Specifications

Speed:..100 WPM (gears available for slower speeds)
Tape levels:....5 or 6
Dimensions:....5⅞" H, 7½" W, 9½" D.
Weight:....Approx. 15 lbs. net
Motor:....Synchronous, 115 V., 60 Cy.
Finishes:....Gray-green or custom

TELETYPE®
CORPORATION
SUBSIDIARY OF *Western Electric Company* INC.

CIRCLE 13 ON READER SERVICE CARD



Why it pays you to specify

BENDIX QWL ELECTRICAL CONNECTORS FOR USE WITH MULTI-CONDUCTOR CABLE

Used extensively on ground launching equipment for missiles and on ground radar, and other equipment, the Bendix* QWL Electrical Connector meets the highest standards of design and performance.

A heavy-duty waterproof power and control connector, the QWL Series provides outstanding features:

- The strength of machined bar stock aluminum with shock resistance and pressurization of resilient inserts.
- The fast mating and disconnecting of a modified double stub thread.
- The resistance to loosening under vibration provided by special tapered cross-section thread design. (Easily hand cleaned when contaminated with mud or sand.)
- The outstanding resistance to corrosion and abrasion of an aluminum surface with the case hardening effect of Alumilite 225 anodic finish.
- The firm anchoring of cable and effective waterproofing provided by the cable-compressing gland used within the cable accessory.
- The watertight connector assembly assured by neoprene sealing gaskets.
- The additional cable locking produced by a cable accessory designed to accommodate a Kellems stainless steel wire strain relief grip.
- Prevention of inadvertent loosening insured by a left-hand accessory thread.
- The high current capacity and low voltage drop of high-grade copper alloy contacts. Contact sizes 16 and 12 are closed entry design.

These are a few of the reasons it will pay you to specify the Bendix QWL electrical connector for the job that requires exceptional performance over long periods of time.

*TRADEMARK

Export Sales and Service: Bendix International Division, 205 E. 42nd St., New York 17, N.Y. Canadian Affiliate: Aviation Electric Ltd., 200 Laurentien Blvd., Montreal 9, Quebec. Factory Branch Offices: Burbank, Calif.; Orlando, Florida; Chicago, Ill.; Teaneck, New Jersey; Dallas, Texas; Seattle, Washington; Washington, D. C.

Scintilla Division
SIDNEY, NEW YORK

Bendix
AVIATION CORPORATION

 CIRCLE 14 ON READER SERVICE CARD

C. Stark Draper

blazed a trail in aerospace

Charles Stark Draper started flying in a Jenny in 1918 right after he graduated from high school. Last year, he supervised the preparation of a proposal for an interplanetary probe that would reconnoiter the planet Mars. In the 41 years between these two events, Draper has been blazing a trail with new devices for measurement and control in the aircraft, missile, and aerospace industries.

The MIT Instrumentation Laboratory, which he heads, is a direct outgrowth of his own research at MIT. Draper describes his entry into the field of measurement and control simply: "I was pushed into it." As a researcher interested in a number of auto and aircraft engine problems, Draper found no instrumentation hardware suitable for the measuresments he wanted to make. When he devised and built his own, he found that the instruments he produced created more excitement than any other part of the research. Just such a situation led to Draper's development of significant devices like engine analyzers, inertial guidance, and optimalizing controls.

"Doc" Draper, (everybody from secretaries to senior scientists at the Instrumentation Laboratory calls him "Doc") started his academic life at the University of Missouri, later transferred to Stanford University, earned a B.A. degree majoring in psychology under Dr. Frank Angell. Because Angell was an experimental psychologist, he stressed measurement of body variables, but the instruments were so bad that Draper decided to try to do something about it. He transferred to MIT, enrolled in the Electrochemical Engineering Department–the closest thing to biochemistry that MIT offered–and earned a B.S. degree in 1926. He switched to areonautical engineering for his master's degree in 1928, and physics for his ScD degree in 1938.

Since he matriculated there in 1922, Doc Draper has been a part of MIT. After his graduation in 1928, he started as a research associate; he was appointed an assistant professor in 1935, an associate professor in 1938, a professor in 1939, and head of the Aeronautical (and Astronautics as of 1957) Engineering Department in 1951. He was made Director of the Instrumentation Laboratory when it was officially set up in 1943.

Draper's first research job in 1926 was with infrared. He developed signaling devices for the Navy, but the project was dropped because the Navy could see no use for such devices at the time.

In 1930, interested in a problem of automobile power plants, Draper started an experiment to learn more about combustion. For the next five or six years he spent most of his time studying this problem: he evolved a mathematical theory, a physical theory, and the instruments to measure them. The final report entitled "Physical Processes Accompanying Detonation in Internal Combustion Engines" served as Draper's doctoral dissertation. But more important, the instruments developed during this study led to the engine analyzers currently used in air transport to locate trouble in internal combustion engines.

With his interest in combustion theory sated, Draper turned to another theory problem in physics. He wanted to apply physics to solve a problem that interested him as an amateur pilot: how to fly without radiation contact with the ground or stars. In the 30's there was no requirement for such a system. But when people became interested in flying over unfriendly territory during World War II, the project was rekindled. While he developed fire and flight control systems for military aircraft at the Confidential Instrument Laboratory (set up in 1940 by MIT with Draper as the first employee), he continued to work the problem of self contained navigation. After World War II ended, Draper's laboratory developed the concept of floating gyroscopes and built the first units (CtE, Oct. '59, p. 85). In

C. S. Draper

. . . headlines in aerospace

corporated in a new approach to navigation, Draper's first inertial navigation system directed an automatically controlled B-29 and C-97 nonstop coast-to-coast, hitting the ships' destinations with good accuracy.

When the ballistic missile entered the weapons stage, inertial guidance became the key to accurate shooting. Today, the Thor IRBM and Atlas and Titan ICBM's use systems based on Draper's pioneering work. And the Instrumentation Laboratory is now actively engaged in designing an inertial system for the Navy's Polaris IRBM.

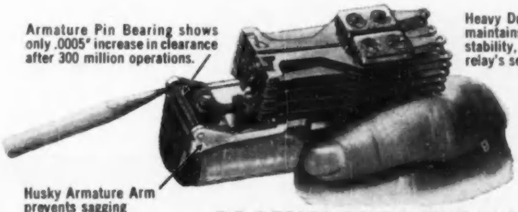
With the major problems of inertial guidance attacked in 1950, Doc Draper's avid curiosity turned to still another problem. One day while watching a test of an aircraft engine in the laboratory, Draper observed how the engineer tediously ran the test, repeatedly changed fuel requirements, read the weight beam on the torque test, and then calculated fuel consumption with a sliderule. Trying to simplify this job led Draper to stimulate the development of "optimalizing controls" which were applied not only to the test arrangement but to actual aircraft to improve the fuel consumption of jet aircraft. His "Principles of Optimalizing Control Systems and an Application to the Internal Combustion Engine", written with Y. T. Lie, is now considered the basic paper in the new field of adaptive control (controls that can change their characteristics with a change in environment).

Draper's other researches, too numerous to mention, span the field of aircraft instrumentation. They include engine indicators (1933), measurement of vibration (1936), sonic altimeter (1937), and strain gages (1949). In addition, since 1950, Draper (with W. McKay and S. Lees) has authored an authoritative series of books, *Instrument Engineering*. Draper and his coauthors are currently straining to produce the fourth volume.

Both the Navy and the Air Force have presented Doc Draper with Merit awards for his technical accomplishments, just two of many that cover an entire wall in his office. But probably the greatest tribute to Draper's work in measurement and control is the Instrumentation Laboratory itself. Started with Doc Draper's own research, the Laboratory today employs over 800 fulltime engineers, scientists and support people, will perform over $16 million worth of research in 1960—continuing the trail blazing of Charles Stark Draper.

HERE'S WHY P&B TELEPHONE TYPE RELAYS GIVE YOU

reliable performance over long life



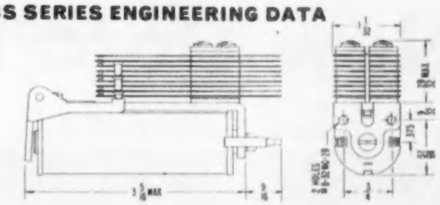
BS SERIES TELEPHONE TYPE

Measure the thickness of the BS series armature arm. You will find the cross section area is greater than ordinary relays of this type. Here is the kind of quality that spells dependability.

Observe that the stainless steel hinge pin runs the full width (not just half) of the armature, providing optimum bearing surface. This pin, operating in a stainless steel sleeve, shows only minimal wear during nearly a *third of a billion operations.*

Best of all, P&B quality costs no more. A whole new plant is being devoted to the production of high performance telephone type relays. Your nearest P&B sales engineer will be happy to discuss your relay problems. Call him today.

BS SERIES ENGINEERING DATA

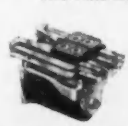


GENERAL:
Breakdown Voltage: 1000 volts rms 60 cy. min. between all elements.
Ambient Temperature: −55° to +85° C. +125° C available on special order.
Weight: 9 to 16 ozs.
Terminals: Pierced solder lugs; Coil: One #16 AWG wire; Contacts: Two #18 AWG wires
Enclosures: Dust covered or sealed

CONTACTS:
Arrangements: DC—up to 28 springs; AC—up to 24 springs
Material: 1/16" dia. twin palladium. Up to 1/4" dia. single silver. Other materials on special order.
Load: 4 amps at 115 volts, 60 cycle resistive
Pressure: 15 grams minimum

COILS:
Resistance: 100,000 ohms maximum; Current: 10 amps maximum
Power: DC—50 Milliwatts per movable arm. Greater sensitivity on special order. AC—17.9 volt-amps.
Duty: Continuous
Treatment: Centrifugal impregnation
Voltages: DC—up to 300 volts with series resistor. AC—up to 250 volts, 60 cy.

MOUNTING: Two #8-32 tapped holes 3/4" o.c. Other mountings on special order.



GS SERIES—Excellent sensitivity: 50 mw per movable arm minimum (DC). For applications requiring many switching elements in small space.

LS SERIES—Medium coil relay with short springs and light weight armature for fast action, reliability and long life.

TS SERIES—Short coil relay is available in AC and DC versions. Long life construction. Can be supplied (DC) with up to 20 springs (10 per stack).

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONIC PARTS DISTRIBUTOR

POTTER & BRUMFIELD

DIVISION OF AMERICAN MACHINE & FOUNDRY COMPANY, PRINCETON, INDIANA

IN CANADA: POTTER & BRUMFIELD CANADA LTD., GUELPH, ONTARIO

unusual capabilities and stability

64 channels in 60″

On these two pages eight fully transistorized Model 860-1500P Preamplifiers appear actual size — each measures approximately 2″ x 7″ x 14½″. In racks of eight, 64 preamplifiers take only 56″ of panel space, and a blower unit another 4″. Necessary power and chopper excitation is provided by a completely transistorized Model 868-500P Power Supply that mounts at the rear of each 8-preamplifier unit, so that no additional panel space is required.

INPUT CHARACTERISTICS
Input circuit guarded, floating, isolated from output, can be grounded. Input impedance 200,000 ohms min. (Preamplifier also available at extra cost with 4-step attenuator with gains of 10, 20, 50 and 100 and smooth gain control to reach any intermediate setting.)

BANDWIDTH
DC to 70 cps (−3 db).

RISE TIME
25 ms to 99.9% of steady state value.

OUTPUT CHARACTERISTICS
Floating, independent of input, can be grounded.
Capabilities: ±1 v across 300 ohms, DC to 70 cps
±1.5 v across 300 ohms, DC to 40 cps
Output impedance 100 ohms. Output is across 300 ohm internal load, shunted by internal 4 mfd capacitance. Part or all of this resistance and capacitance can be supplied externally, in any combination to suit your application.

LINEARITY
±0.1% of full scale output (2 volts)

GAIN
100 (10 mv input for 1 volt output). Preamplifier with gain of 1000 (1 mv input for 1 volt output) also available on special order. Gain stability ±0.1% for min. of 24 hours.

INPHASE REJECTION RATIO
120 db at 60 cps, 160 db at DC, with 5000 ohms unbalance in source.

INPHASE TOLERANCE
250 VDC, 220 VAC

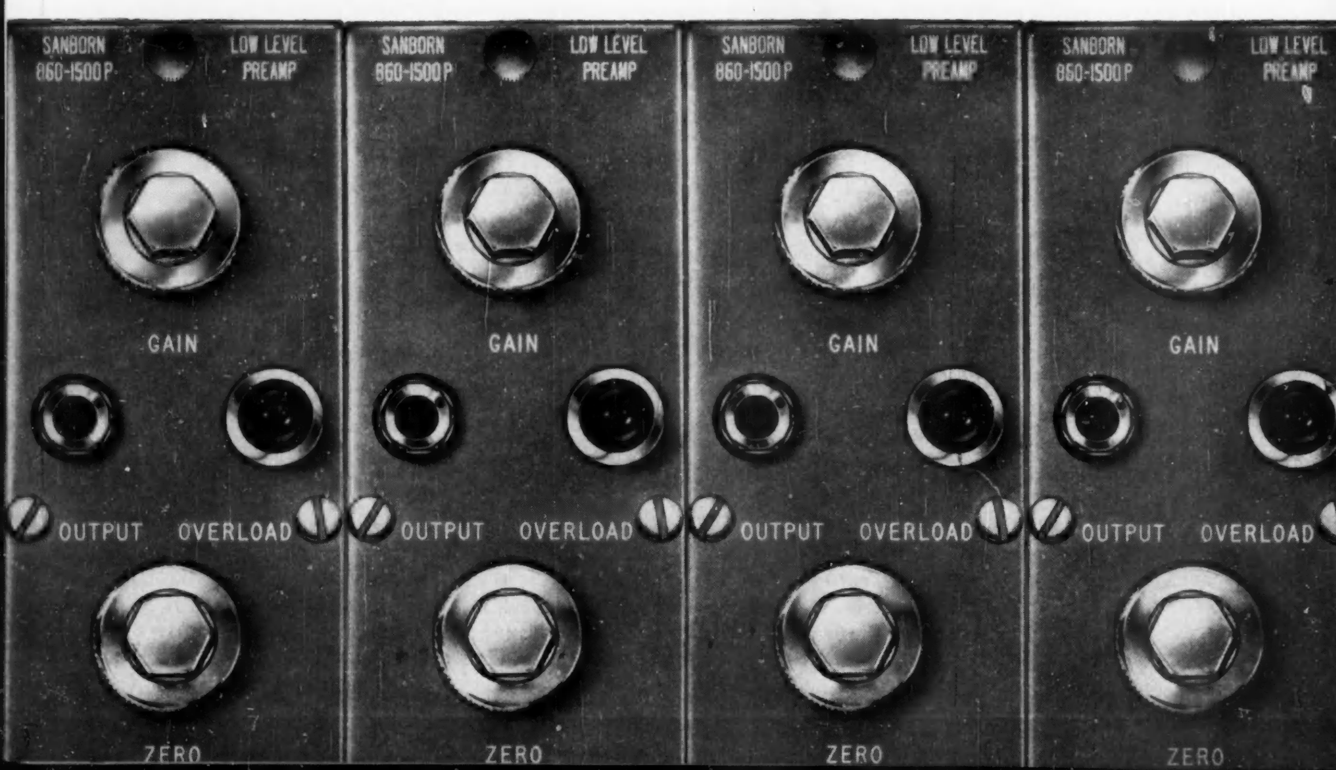
NOISE
2 uv peak-to-peak referred to input (measured over DC to 100 cps). Noise plus ripple for full scale signal not to exceed ±0.1% of signal (measured wide band-ripple is 880 cps).

DRIFT
±2 uv referred to input, at constant ambient temperature, after 30 minutes' warm-up. Input drift temperature coefficient ±0.2 uv/°C, max.

OVERLOAD RECOVERY
Preamplifier recovers from fully blocked condition within 20 milliseconds after removal of signal. 10 volts of signal at input will not damage preamplifier.

POWER REQUIREMENTS
Each Preamplifier requires 2.5 watts; Model 868-500P Power Supply handles up to eight Preamplifiers.

New Data Preamplifier model 860



$462.50
per channel, complete

Each Model 860-1500P Preamplifier costs $400, each Power Supply for every eight Preamplifiers, $500. Consider the substantial savings over equipment with comparable specifications — when economy "per channel" is multiplied by the number of channels you're using. (All prices are F. O. B. Waltham, Mass., within continental U. S. A.)

What distinguishes this data preamplifier from others is *not* its specifications *alone*— but the *combination of this performance with high reliability, practical cost* and *small size.* Together, they make the Sanborn Model 860-1500P the logical choice for data processing systems in which tens or hundreds of channels of information must be handled.

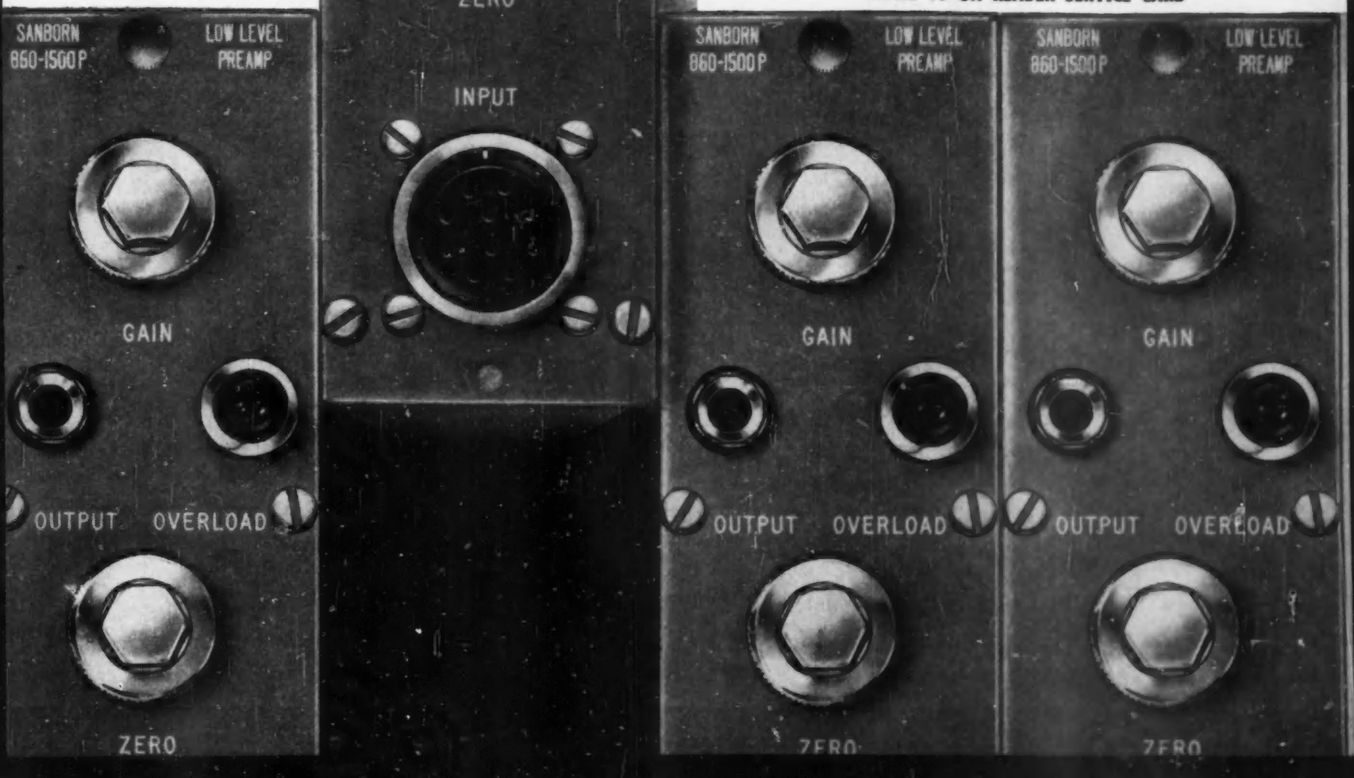
Completely transistorized, the 860-1500P is designed for amplifying low level inputs such as thermocouple, strain gage and resistance bridge outputs. Typical outputs include digital voltmeters, tape recorders, scopes and other readout devices.

Complete engineering data and application assistance is available from Sanborn Company. Contact your nearest Sanborn Industrial Sales-Engineering Representative, or write the main office in Waltham, Mass.

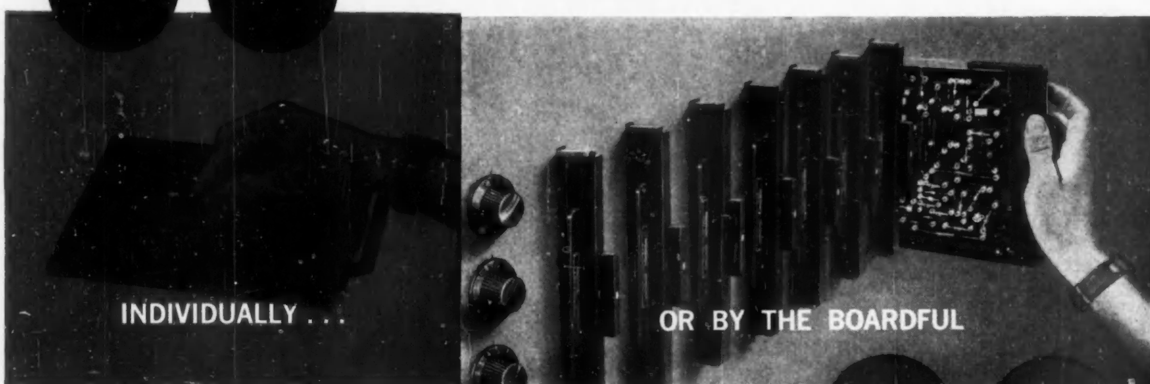
-1500P

SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman St., Waltham 54, Mass.

CIRCLE 19 ON READER SERVICE CARD



INSTANT



COMPONENTS...

For the first time, here is a component programming device in which the number of inter-chassis connection points is directly related to the chassis area. Without wrenches, soldering irons, or other equipment—you can instantly replace your mounted components, singly or by the hundreds with AMP's all new "816" Pluggable Chassis. These units can be stacked like books on a shelf to save you space and weight and you save also on the number of units and intercircuit connections you use compared to other techniques.

CHECK THESE IMPORTANT FEATURES:

- Contact Pins—crimp-type, with positive detent and firm component-lead support against shock and vibration. Other type contact pins can be accommodated.
- AMP's Exclusive Contact Wiping Action—just slide the chassis into the frame, rotate locking handles and contact surfaces on pins and their mating springs are pre-cleaned.
- Encapsulation—you can pot the entire chassis or lock groups of components into the chassis.
- Reliability—the same high quality construction and performance found in AMP's Patchcord Programming Units.
- Adaptability—other pluggable chassis units are available in a variety of sizes and hole arrangements as required by your specifications.

For more information write to:

AMP INCORPORATED

GENERAL OFFICES: HARRISBURG, PENNSYLVANIA

A-MP products and engineering assistance are available through subsidiary companies in: Australia • Canada • England • France • Holland • Japan

←CIRCLE 21 ON READER SERVICE CARD

CIRCLE 22 ON READER SERVICE CARD

Newsbreaks In Control

● Atlas to Fly with Inertial Guidance

Cape Canaveral—First tests of an Atlas missile guided by a selfcontained inertial system are slated for January. The switch to test firings with American Bosch Arma's inertial system indicates that the Air Force is now satisfied with the radio control system which, built by the General Electric Co., has controlled all previous Atlas tests.

● AF to Study Hot Gas Controls

Dayton, Ohio—Air Force Flight Controls Laboratory is evaluating proposals to build a general hot gas control system. The project, the first on a systems basis, is aimed at solving some of the problems of materials, gas sources and dynamics of hot gases. The system will include a gas generator, gas servos, and actuators. It will generate gas to operate the servos to move aerodynamic surfaces and swivel rockets, be the working medium in reaction controls, and provide pneumatic computation. Signal pickoffs and transmission will all be pneumatic.

● Capacitance Gage Spots Water in Fuel

Philadelphia—Airline and Air Force officials are evaluating a new on-line capacitance gage developed by an oil company to spot water in jet fuel. In tests at the airport here, the device was able to spot as little as 100 ppm of water in fuel while it was flowing at standard fill rates. The oil company plans to put the device on the trucks that service jet liners; the gage will either sound an alarm or shut off the flow of fuel if water is spotted.

● New Relay Performs Hundred Million Operations

Chicago—C. P. Clare Co. will unveil a radically new relay at the March IRE show, says parent company (Universal Controls) president M. Mac Schwebel. Called the Clareed Sealed Contact Reed Relay, the new unit is only 2 in. long, will perform millions of operations, hundreds of millions at half rated load. Each pair of contacts is hermetically sealed in a glass capsule. Relays will be available in many forms: from one contact capsule and one coil on up.

● New Control Computer to Debut

Los Angeles—Packard Bell Computer Corp. will announce a startlingly small general purpose computer for control applications in March. Packaged to take up only 20 in. vertically in a standard equipment rack (19-in. wide) and all solid state, the new computer is intended as a system component rather than a laboratory tool. And it will have a new type of memory. Other features: high speed storage on the order of a few thousand words, extremely fast multiply times measured in microseconds, and a price tag "well under $50,000".

Deliver First Polaris Checkout Gear

Navy's missile will have computer-controlled automatic checkout equipment testing it from factory to countdown. First installation, for checking missile parts in the factory, was delivered last month.

LOS ANGELES—First fully automatic production test equipment for the Navy's Polaris missile was delivered last month to the Sunnyvale plant of prime contractor Lockheed Missiles and Space Division. Built by Packard-Bell Electronics, the checkout gear will automatically test and verify at Lockheed the readiness of missile components, missile assembled packages, and complete missile systems. It will make the final checkout for Navy acceptance of a specific missile.

Automatic checkout has been ordered for every phase of Polaris assembly, from the factory to prelaunching in the submarine. The Navy's philosophy has been named Acre, Automatic Checkout and Readiness Equipment, and has been applied in four areas: *Acre/Nirop*, *Acre/Nwa-Ipb*, *Acre/Asb*, and *Acre/Ssnb*. *Nirop* means Naval Industrial Reserve Ordnance Plant, the place where missiles will be initially built. *Nwa* stands for Naval Weapons Annex (with a Missile Assembly Building and an Inert Processing Building) where missiles are assembled prior to issuance to submarine tenders, which will carry the weapon. *Asb* refers to the tender on which operations will be carried afloat. And *Ssnb* identifies equipment that will be carried in the missile launching submarine.

Packard-Bell's first delivery was *Acre/Nirop* equipment. It consists of a special purpose digital computer and a test station. P-B has a $1.2 million contract for *Acre/Nirop* gear, and will deliver 4 more test stations.

Acre/Nirop's computer serves as a central station, controlling a series of peripheral test consoles. (Originally, the testing complex was called *Acre/Octopus* because it resembled an octopus with its central control and arms reaching out to up to eight test stations.) The computer sends out test control signals — programming the proper signal generators—receives test data reporting performance characteristics (functional and qualitative), and compares the performance to preset limits.

The five test stations of *Nirop* will be scattered throughout the factory at points where they can be best used for the tasks to be performed. Any station can be equipped to perform any test. The system has four major testing functions:

- ▶ check overall missile system (less the nose cone). Test involves a complete checkout.
- ▶ Check a partial system that is a combination of two or more subsystems. Typical example: all of the first stage packages assembled together and an interlock package.
- ▶ Check "packages" such as the flight control package.
- ▶ Check components and modules such as printed circuit boards.

To start a test, the test station interrogates the central computer. Punched cards input to the test station identify the part to be tested and the tests required. Here's how a typical test would proceed:

Step 1. The operator connects unit to be tested—missile component, package, or completed system—to test console with a cable harness.

Step 2. Operator inserts into a card reader a punched card associated with the unit to be tested. Information from the card is transmitted to the central station, advising type of unit to be tested and the tests required.

Step 3. Central station computer identifies the proper test and begins testing operation by sending the "address" of the test to a decode matrix in the test console, thus connecting the appropriate test module with the switching matrix.

Step 4. Another signal from the central station then programs the module to the desired output level for the test.

Step 5. Switching matrix connects test module with the unit under study. At same time, output of the unit under test is connected to the central station and a first reading of test is delivered.

Step 6. At central station, computer compares the test value with limits contained in its memory, determining if the value is within the preset limits.

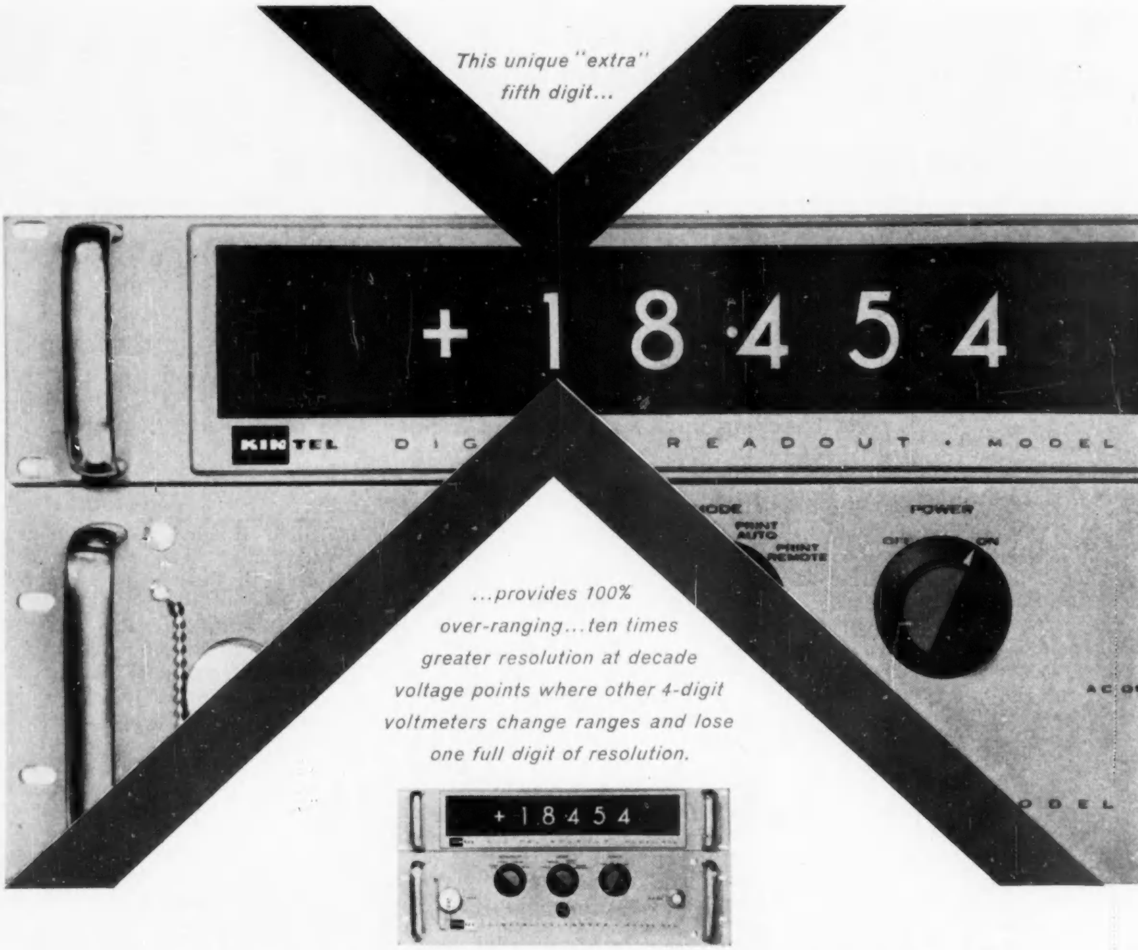
Step 7. If the value is within limits, the computer station sends a "go" signal which permits the continuance of testing. If the value is not within limits, the central station prints out the actual test value and stops the operation. The computer also prints out what is wrong and how far off the readings are from the limits.

Step 8. If the first value is within limits, investigation automatically proceeds to test number two.

During the testing operation, the computer and test stations perform a number of internal checks to insure that the test setup is functioning correctly. Calibration of instruments is inherent in the system, continuous after each test. Test length may vary from a fraction of a second to a maximum of two minutes for a complete system check.

The test station consoles are built with equipment in drawers. Any of the test stations can be given the capability of performing any of the test functions. Components include: decoding matrix, relay chassis, line amplifiers, various programmable power supplies, and programmable signal generators. A built-in maintenance unit troubleshoots the test console.

—Kemp Anderson
McGraw-Hill News



The KIN TEL Model 501 4-digit, over-ranging digital voltmeter measures DC from ±0.0001 to ±1000.0 volts with 0.01% ±1 digit (of reading) accuracy. An extra fifth digit in the left decade indicates "0" or "1" to provide ten times greater resolution at decade (1, 10, 100) voltage points than standard 4-digit voltmeters. Ranging and polarity indication are entirely automatic. The measured voltage, decimal point and polarity symbol are displayed on an in-line readout in a single plane–no superimposed outlines of "off" digits.

An adjustable sensitivity control permits decreasing sensitivity to allow measurement of noisy signals. Ten-line, parallel input printers can be driven directly, and converters are available for driving other types of printers, typewriters, and card or tape punches. The input may be floated up to 25 volts DC above or below chassis ground with no degradation in performance, and up to 250 volts DC with slight decrease in accuracy. Stepping-switch drive coils are energized with DC as in telephone-type service to provide long, trouble-free operation.

The 501 is one of a complete line of KIN TEL digital instruments. Others include AC converters, AC and DC preamplifiers, ratiometers, and multi-channel input scanners.

IMPORTANT SPECIFICATIONS

Display...Six decades display 5 digits (Left digit "0" or "1" only), decimal point, polarity symbol. Ranging and polarity indication are automatic. Projection system readout employs bayonet-base lamps with 3000-hour minimum life rating. Readout contains no electronic circuitry and can be remotely mounted.

Automatic Ranges...±0.0001 to ±1000.0 volts DC in four ranges: 0.0001 to 1.9999; 02.000 to 19.999; 020.00 to 199.99; 0200.0 to 1000.0

Accuracy...0.01% ±1 digit (of reading).

Input Impedance...10 megohms on all ranges at null.

Reference Voltage...Chopper-stabilized supply, continuously and automatically referenced to standard cell.

Stepping-Switch Drive...DC voltage within stepping-switch manufacturers rating applied by transistor drive circuit at rate of approximately 20 steps per second.

Controls...Three: on-off; sensitivity; and mode of operation (standby, normal, print auto, print remote).

Printer Drive...Built-in for parallel input printers. Automatic or remote.

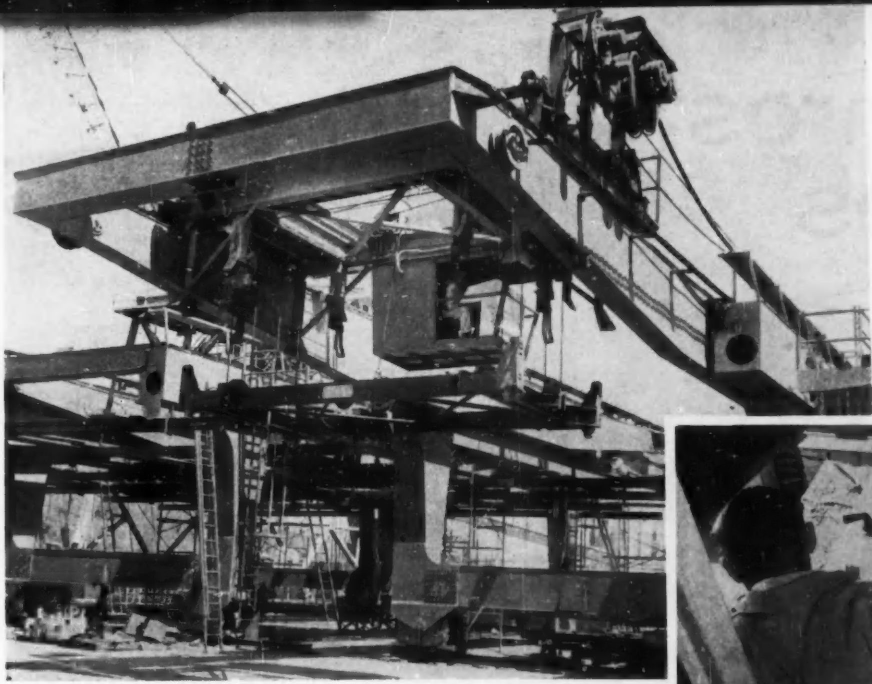
Dimensions and Net Weights...Control unit: 45 lbs, 5¼" H x 19" W x 16" D. Readout: 10 lbs, 3½" H x 19" W x 9" D.

Price: $2995

KIN TEL manufactures electronic instruments for measurement and control, and closed circuit TV. Representatives in all major cities. Write for detailed literature or demonstration.

KIN TEL
A DIVISION OF
COHU
ELECTRONICS, INC.

5725 Kearny Villa Road, San Diego 11, California, Phone: BRowning 7-6700



New shipboard cranes, automatically controlled, cut loading and unloading time by 66 percent. Operator can place a container into proper position in ship's hold by pressing proper numbered button in center of control console.

Automatic Cargo Controls Sail with Freighters

Grace Lines has installed shipboard cranes with automatic controls to speed loading and unloading containers of cargo.

SAN FRANCISCO—

Six radically designed, automatically controlled, shipboard cranes will handle cargo on two Grace Lines freighters—three cranes to a ship. Designed to load and unload cargo in aluminum containers, the new cranes reduce time for the average loading operation from three days to less than one. Additional cash savings are expected from lowered insurance rates, the result of virtually stopping cargo pilferage and damage (the cargo is preloaded and sealed into square aluminum containers which are then loaded into the hold of the ship).

Cost of the installation was in excess of $1 million. The 22.5-ton capacity cranes were engineered and built by Pacific Coast Engineering Co., installed at the Maryland Shipbuilding and Drydock Co., and controls supplied by Rundel Electric Co. of Millbrae, Calif. The controls not only direct automatic loading and unloading, but also compensate for ship list as loading proceeds.

• **Sliding girder**—Design of the crane itself marks a radical departure from conventional shipboard lifting devices. The Grace cranes have a sliding boom with a telescopic bridge girder that rolls on wheels. The girder can extend on either side of the ship. Because of this sliding boom design, instead of the conventional "birdwing" crane, the entire superstructure of the lifting mechanism is much lower when not in use, improving visibility from the wheelhouse.

Grace had to rely on shipboard cranes instead of land-based devices because many of its ports of call do not have container handling gear.

• **Within 2 in.**—With the Rundel control system, the crane can move up to 476 cargo containers to within 2 in. of their designated positions in the hold. To do this, the operator merely has to punch the proper button, out of 36, on the console.

By setting the controls to "Unload" and pushing another button, the operator can direct automatic unloading of the hold.

For automatic unloading, the hoist is directed over the designated container, a spreader is lowered until it locks on the container, and the container is lifted out of the ship and over the side. At this point, automatic control ceases. A crane operator takes over and guides the load to the point on the dock (usually a truck bed) designated for it. The manual control of unloading can be performed from the crane cab or from the dock with a pendant control box which is tied in electrically with the control console.

On the loading cycle, manual control is exerted until the container is over the ship. Automatic control is then cut in, and it directs the con-

WHAT'S NEW

. . . heavy pendulum in oil compensates for ship list . . .

tainer to the proper cell in the hold without further guidance.

• **First shipboard cranes**—Although automatic cranes are not new, the shipboard units are an innovation. The control system also has to cope with the problem of ship list. When a ship is unevenly loaded or when a heavy container swings out over the dock, the control has to compensate for the list so that a container being handled by another crane will not miss the hatch or land in the wrong cell.

A specially designed heavy pendulum, swinging in a damping bath of transformer oil regulates compensation. Two phenolic cams, that can rotate as the pendulum swings, are attached to the pendulum shaft. As the pendulum swings with ship list, the cams rotate until they actuate switches which energize the appropriate crane creeper motors. When crane has moved to compensate for list, pendulum returns and cams open switches, stopping crane movement.

The sensing device is actuated by a list of more than a quarter of a deg; it will operate automatically up to a list of 6 deg. If list passes 6 deg, the pendulum moves so much that it actuates a switch to cut out the automatic control and advise the operator to take over manually.

• **Labor's reaction** — Probably the most touchy part of the automatic control is the reaction of labor unions to the automatic loading and unloading. Using containers, the ship lines need fewer stevedores for a shorter period of time. There is no indication, as yet, as to how the International Longshoremen's Association, which controls East Coast ports, will react to the arrangement.

In the past, ILA has been dead set against any automation.

On the West Coast, where the docks are run by a different union, the Pacific Coast Maritime Association has worked out a profit-sharing scheme to offset some of the onus of automatic machinery. Shipowners have set up a special fund out of which longshoreman will be paid bonuses commensurate with the amount of work they have lost to equipment.

Shipowners feel that automatic techniques will save more than the cost of the fund. Eventually, the subsidy will be reduced as fewer longshoremen are recruited.

—Donald Winston
McGraw-Hill News

Zeus Production Plans Derailed Again

Defense Dept. turns down Army request to start producing anti-ICBM components before R&D is completed. The decision will affect builders of machinery controls as well as those working directly in control areas of the project; first expenditures were to have been for machine tools and automatic machinery.

WASHINGTON—The Defense Department has turned thumbs down for the second successive year on the Army's proposal to begin production of subsystems and components on the Nike Zeus anti-ICBM system before the system has completed the research and development phase. Army planners had requested $700 million in the fiscal 1961 defense budget to start procurement of the longest lead time elements of the system. Included were such items as construction of manufacturing facilities and purchase of machine tools and other automatic machinery to build computer elements.

Zeus is an outgrowth of the Nike Ajax and Nike Hercules antiaircraft systems now deployed across the nation. It is designed to detect and track ocean-spanning ballistic missiles and to destroy them in the upper atmosphere during the terminal stage of their 15,000-mph ballistic trajectories, at least 200 miles away from the defended area.

• **Opposing Zeus**—Behind Defense Dept.'s turndown of the Army's production plans are at least two reasons: one political, the other tactical. On the political side is the presidential election in 1960, and the Eisenhower Administration's firm intent to hold next year's defense expenditures to the current $41 billion level. The budget pinch has already resulted in cutbacks, stretchouts, and cancellations for both development and production programs (see p. 95).

Even more important, however, is the philosophical objection to Zeus. A widely held view in Washington these days is that the U. S. defense picture would be strengthened more by stressing expenditures on retaliatory weapon systems such as ballistic missiles, Polaris-firing submarines, manned bombers, and other nuclear striking forces rather than by investment in a purely defensive system such as the Zeus anti-ICBM.

For 1960, R&D on Zeus will continue to roll along at about the same rate it has been progressing. Some tests of key components and subsystems are scheduled for this year. The first full scale system test has been slated for 1962 on Kwajalein atoll in the Pacific. Here, then, is the current status of the Nike Zeus project.

• **Proposed performance**—Zeus specifications call for (1) a three-stage, solid rocket, surface-to-air missile with a booster producing about 450,000 lbs thrust at launch; (2) highly powerful and sophisticated forward and local acquisition and missile tracking radars; and (3) a computer control center with a greater traffic load capacity than any computer built and a speed at least as great as the SAGE air defense system's IBM-built FSQ7A, the fastest computer now operational.

Since 1955, the Army has invested some $500 million in research and development on the Zeus system. At this point, there have been two short range, unguided test launchings of a missile prototype at the White Sands Missile Test Range, N. M. The last one, on Oct. 14, was termed "successful" by the Defense Dept.

In addition, radar prototypes and all modules of the computer are now being installed at White Sands for further testing. The full scale test of the complete Zeus system is scheduled for 1962. At the time of the Kwajalein test, an operational-type missile will be fired against actual ballistic missile targets launched from Johnston Island, at least 1,500 miles away. Until then, Zeus will be test fired from White Sands—and later from Pt. Mugu, Calif.—its computer programmed with synthetic targets.

• **Why concurrent R&D**—For the second successive year, the Army recommended that production of Zeus subsystems and components be started

WHAT'S NEW

. . . Army says Zeus is where we can risk production . . .

before the project's R&D phase is completed. The Army pleaded for "concurrent" R&D and production as a means of pushing Zeus into an earlier operational status. Says Maj. Gen. W. W. Dick, Jr., the Army's Director of Special Weapons R&D: "Zeus development is at a point where [we can] proceed to production within a reasonable area of risk."

There's some history to back up the Army's claim. Production of subsystems and components was started on the Air Force's Thor, Atlas, and Titan and the Navy's Polaris ballistic missiles before completion of R&D.

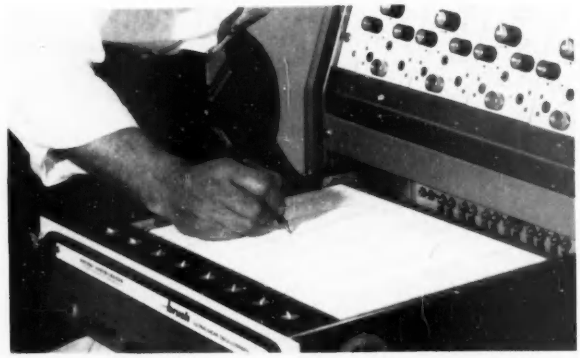
• **Spending plans** – The Defense Dept.'s budget plan for fiscal 1961, starting next July 1, calls for a fund of roughly $300 million to continue R&D work on Zeus. This is about the same level as the project's budget for the current fiscal year.

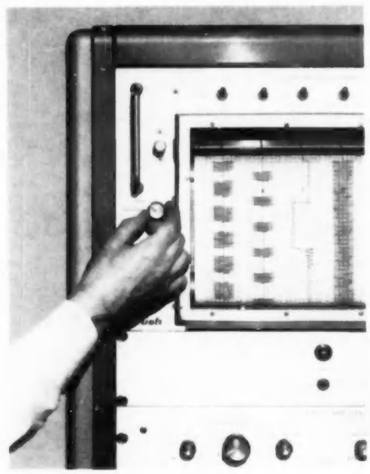
Tied to the fiscal 1961 budget plans is the question of whether the Army will be allowed to spend $137 million extra which Congress appropriated last summer for "pre-production" work on Zeus during fiscal 1960. This was in addition to the $300-million R&D funds for the project.

• **Decision Makers**–The question of Zeus's future depends to a large extent on recommendations made to the Defense Dept. and to the White House by a group of top bracket scientific advisers who have made a technical evaluation of the project. The group is headed by Dr. Hector Skifter, the Pentagon's assistant director of research and engineering for air defense, and Dr. George Kistiakowsky, President Eisenhower's special assistant for science and technology. Skifter, who's on leave as president of Cutler-Hammer, Inc.'s Airborne Instruments Laboratories, reportedly backs the Army's recommendation.

Ex-Defense Secretary McElroy, on the other hand, put his thinking this way before a congressional committee last year: "we might be better defended if we use (defense funds) for aggressive potentialities. Our ability to deliver destructive weapons on an enemy would have more [of a deterrent] effect on him than our ability to defend ourselves against his weapons."

In essence, this is the old argument that the best defense is a strong offense. According to preliminary Pentagon estimates, the total cost for an operational Zeus program (envisaging missile batteries at 50 U. S. target centers) would amount to at least





WHAT'S NEW

. . . Is this adequate defense for a cost of $10 billion? . . .

$10 billion. The Army claims the first Zeus site could be operational four years after an official green light for production.

• **Unenthusiastic view**—The predominant Washington feeling on Zeus is represented in this recent statement by one of McElroy's top aides: "We must be assured first that Zeus will work. But even then we have to evaluate the necessity of production in terms of the decree of Zeus's potential performance against the threat. If it were a matter of defense against only one oncoming missile on a target we would buy Zeus.

"The threat, however, is of salvos of ballistic missiles on a target—accompanied by decoys among which it will be hard to discriminate. Even if we assume Zeus's effectiveness against as many as 80 percent of the enemy's missiles—which is very questionable—how much have we really accomplished if 20 percent still hit us with thermonuclear warheads? Is this adequate defense to justify the cost of Zeus?"

• **Zeus's team**—A team of at least 40 major companies and research institutions is working on the Zeus project. Western Electric Co. is the prime contractor. Bell Telephone Laboratories, its AT&T affiliate, is in charge of system development—including the computer-control center.

Douglas Aircraft is subcontractor for the missile. Lear is developing and building the missile gyro platforms; Remington Rand Univac, a guidance computer; Ryan Aeronautical, radar seeker; Sperry Gyroscope, target track radar; RCA, transmitters; Firestone Tire and Rubber Co. is in charge of instrument tests; Packard Bell Computer Corp. is working on a digital computer; Goodyear Aircraft, acquisition antennas; Airtone, Inc., radar.

• **Operational program**—As the Zeus anti-ICBM system is now planned, initial warning of an enemy ballistic missile launching would be provided by the Air Force's ballistic missile early warning system (BMEWS). This system will consist of three radar sites with a range of 3,000 miles each. The first site is under construction at Thule, Greenland (it will be operational late next year); others are planned near Clear, Alaska and Newcastle, England.

BMEWS will detect an enemy missile during the apogee of its 30-min flight, providing a warning of some

←CIRCLE 34 ON READER SERVICE CARD

CIRCLE 35 ON READER SERVICE CARD

WHAT'S NEW

. . . Zeus is designed to carry out its mission in 4 minutes . . .

15 min. Zeus's second line of warning will consist of about six forward acquisition radars—with a range of about 600 miles—deployed through mid-Canada. These highly powerful, sophisticated radars will also establish the initial track on the oncoming missile. The Zeus forward acquisition radars will be equipped with new high power klystron tubes (developed by Sperry Gyroscope) which generate more power per wavelength than any microwave radar tube now in use.

In the next phase, target and missile tracking radars at the launching site take over to automatically compute the course for the intercept missile. Plans are to install three target track radars, nine missile tracking radars, and 50 missiles per Zeus site.

• **Lock on Radars**—In a typical engagement, the target tracking—or local acquisition—radars will lock on and precisely track the incoming target. The other tracking radar will lock onto the Zeus intercept missile. Both radars will provide continuous position data to the computer. The computer will guide the intercept missile by radio command.

For vectoring purposes, the missile will have a small third stage rocket in its warhead. The steering will be accomplished by exhausting through canard fins.

The Zeus warhead's destruct techniques are highly classified. But it will probably destroy the attacking warhead through atomic or thermal radiation produced by a nuclear explosion or through explosions of particles in the attacking warhead's path. Impact of such particles could erode the enemy warhead.

Zeus is designed to perform its mission — launching and interception — within a period of 4 min. This fantastic chore is supposed to be accomplished at least 3 min. short of the defended area.

• **Decoy or not decoy** — Pentagon critics say the major weak spot in Zeus is the system's inability to discriminate against highly sophisticated decoys—that is, decoys with the appropriate weight-drag ratio and radar characteristics to behave like the actual warhead.

Zeus proponents say the system's circuitry and computation can sort out less sophisticated decoys such as the oncoming missile's tankage. They concede the problem of decoy discrimination at this stage of development.

—Morton Reichek
McGraw-Hill News

← CIRCLE 36 ON READER SERVICE CARD

WHAT'S NEW

NEMA Systems Group Aims at Semantics

ATLANTIC CITY—
NEMA's (National Electrical Manufacturers Association) Industrial Automatic Systems Section reported progress in two important areas at the Association's annual meeting, making its first report since it was founded last January. The Subcommittee on Definitions under Chairman R. N. Eck (Cutler-Hammer) has defined about 100 terms covering general control system terminology, electrical drives, and feedback control systems. Next step: definitions for data processing, programming, and computing systems. The terms that have been agreed upon are now proposed for acceptance as NEMA standards.

At the same time the task group investigating the system compatability of components (chairman: A. G. Mueller of Square D Co.) has decided to start its study program by looking into shaft encoders, transistors, controlled rectifiers, and diodes. The group's goal: to establish standards for system performance by evaluating present rating techniques and the application problems they create.

The General Engineering Committee continues to study the problem of minimum creepage distance for circuits under 50 volts to determine practical spacing requirements for plant-site applications. In addition, another subcommittee will study regulated systems standards—but personnel has not yet been assigned.

Section officers were continued in office for another year: D. L. Pierce (Westinghouse Electric Corp.) remains Section chairman, and William Alvarez (General Electric Co.) chairman of the Section's General Engineering Committee. One new company, Lear, Inc., joined the member companies (CtE, July 1959, p. 30), bringing the total to 11.

Programming Seen as Key Problem in Computer Application

CHICAGO—
Programming—and how to make it easier for engineer users of computers —was the hottest subject of presentations and discussion at the Computer Applications Symposium sponsored by Armour Research Foundation in Oc-

tober. Because the number of computer installations is increasing faster than the supply of new programmers, there is an increasing need for automatic programming techniques and courses to train users.

Charles Katz, manager of General Electric's Automatic Computer Coding Dept., stated the problem: "There is an ever-growing number of 'non-programmer' users of computers. These are persons who are expert in their own fields, who know the problem or system for which they want results, and who want to use a computer as a tool to get these results in the quickest, most economical way."

To service such users, Katz sees computers being delivered to customers with automatic programming systems and synthetic languages. The GE manager predicted that the basic machine code would not be made available. All training and programing would take place at the source language level. And he envisioned a day in the near future when automatic programming systems will be built modularly, using the same source language on all models.

Another aspect of the problem—capability of present programmers—was aired by E. J. Albertson, U. S. Steel's Methods Planning Div. He told the symposium, "More programmers cannot solve the problem since there appears to be a limit to the number that can be used on each application. The answer appears to be more programming per programmer, by increasing automatic programming."

A Westinghouse engineer, Frank Engel, reported his experiences teaching "non-programmer" computer users how to use Fortran (a computer language) with the IBM 704. "Although we felt moderately successful in bringing the power of Fortran and the 704 to the engineer, we were disturbed because only 20 percent of those taking the course succeeded in putting problems on the computer. It may not be such an unfavorable statistic, however. In a sampling survey of the students, everyone replied that he was sure he could write a Fortran problem, but he didn't have any problems amenable to computer solution; or, he didn't have the funds in his budget; or, he had taken the course to learn about computers."

Engel concluded that his course should also teach an understanding of what problems confronting the individual student can be put on the computer and teach him to organize the problem for solution.

EUROPEAN REPORT

Fear of Government Regulations Slows British Nuclear Controls

LONDON—
Study of ways to use nuclear energy in control applications is well advanced in Great Britain, but applications trail far behind the theory as industrial users are reluctant to make installations. Most frequently blamed for the delay are proposed complicated industrial rules that would regulate installation of radioactive materials.

The British government is still thrashing out a set of proposed work rules with users and manufacturers of the equipment, and the possible outcome has scared potential users. For example, one provision that has been suggested would require full health monitoring and film badge protection in any installation with a radioactive source emitting in excess of 30 milliroengtens per week. The prospects of having to set up such an organization and the expense have cooled many British industrialists.

If the work rules can be resolved satisfactorily, however, at least three British companies are ready to serve the market. Baldwin Controls has concentrated on thickness gages for the paper industry, developing the Brehmstrahlung back scatter method (CtE, April '58, p. 105) so that thickness ranges were extended to 0.080 in., and the equipment can also be used on metal strip gaging.

Ekco Electronics first concentrated on the cigarette industry in a joint venture with American Machine and Foundry. Now Ekco has set its sights on metal and plastic thickness applications with a Brehmstrahlung gage.

Isotope Developments Ltd., has concerned itself primarily with simple on/off level controls for the packaging industry. But it too has recently expanded, now make a Brehmstrahlung gage for long term corrections of thermal deformations on the steel mill stand and rolls in the Davy-United automatic gage control system.

Both Baldwin and Ekco provide error signal outputs for control as standard equipment on their gages. Baldwin offers intermittent proportional control with a fixed dead zone. Ekco combines production with 95 percent proportionality by operating time proportional on/off servos.

Enough prototype applications have been made to give the nuclear measurement and control industry (now grossing about $450,000 per year) a suitable showcase in Britain. Here are some examples:

- Most sophisticated installation in the oil industry was made by Ekco. Nine fluid density gages monitor interface travel on the 555-mile Iraq Petroleum Co. pipeline from Kirkuk to Tripoli. At each pumping station and at the terminal, gamma radiation measuring heads are fitted both at the switching point and 3,000 yds upstream. At the interface the two products in the line absorb gamma rays differently. Density variations in specific gravity as low as 0.001-0.002 can be detected.

The Ekco equipment has alarm circuits to alert the station operator when the interface approaches the advance warning point and then on arrival at the switching point. Temperature sensing elements on the pipeline, upstream of the radiation heads, compensate for any change in temperature.

The installation saved 80,000 gallons of crude oil during the first tests. An unexpected advantage: the detectors were able to spot the location of sludge carried into the pipeline from the bottom of storage tanks.

- In the steel industry a showpiece installation has been set up by Steel, Peech and Tozer, a subsidiary of U. S. Steel Co. Ltd., to supply a visual display of strip profile on a hot strip rolling mill. This installation of Baldwin equipment enables the operator for the first time to see the overall thickness of the strip as it is rolled.

The display consists of 48 vertical rows of lamps, five lamps in each row. Middle lamps of the row indicate "on tolerance"; two adjacent amber lights show "within tolerance" strips; and the outer lamps in each row show "off tolerance". Accuracies of 1 percent are claimed for the Brehmstrahlung gages measuring strip thicknesses from 0.03 to 0.25 in.

- Ekco has also installed a three-loop cascade system on a double sided rubber calendaring plant. Normal Beta ray gages measure the coating thickness of rubber composition on the top and bottom surfaces of the backing material. Adjustment of the set points controls the thickness between the top and bottom surfaces.

—Derek Barlow

Italian Control Makers Try Something New: Electronics

Electronic instrumentation and control make rapid inroads at the Fourth Milan Instrumentation and Automation Show.

MILAN—
Last year, visitors to the Milan Instrumentation and Automation Show had little to report back that was new or exciting. This year, however, a new trend was obvious: electronic control systems are making rapid inroads in Italy.

Firms like Olivetti, Italy's sharp marketer of business machines and typewriters are setting the pace. Olivetti, for example, unveiled a brand new computer and an electronically controlled milling machine.

The new computer, the Elea 9003, is the first computer built entirely by an Italian company. It is completely transistorized, has a core memory, and is intended for both business data processing and engineering problem solving. Information can be fed in by punched tape, punched card, or magnetic tape. Output is punched card or Teletype punched tape. The core memory can be expanded to 160,000 characters and magnetic drum memories are available accessories.

Olivetti says the machine is plurisequential, meaning it can process more than one program at a time. According to an Olivetti representative, each program is automatically timed; an automatic priority system allows processing three programs simultaneously without interruption.

As accessory equipment, Olivetti displayed an off-line converter that puts punched card or punched tape information onto magnetic tape. The converter has two photoelectric punched-tape readers capable of scanning 800 characters per sec; the card reader can read 700 cards per min.

The milling machine that Olivetti demonstrated was an electrohydraulic machine, electronically controlled by a fixed program. It has mass produced breaker arm support plates.

Another Milanese company, Officine Guardigli, was showing a new system to meter the feed of reciprocating rolling mills. It uses a photoelectric device to register the motion of the rolling mill carriage.

To do this, piston motion is transmitted to a soup-plate shaped wheel

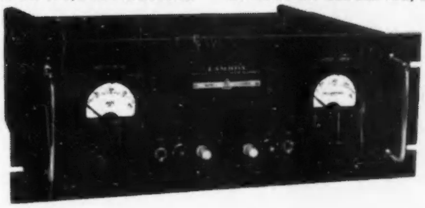
Three voltage ranges: 0-200, 125-325, 325-525 VDC

1.5 AMPERE MODELS **NEED ONLY 8¾" OF PANEL HEIGHT!**

(metered)		(unmetered)	
MODEL C-1580M:	0-200 VDC, 0-1500 MA. 580.00	MODEL C-1580:	0-200 VDC, 0-1500 MA. 550.00
MODEL C-1581M:	125-325 VDC, 0-1500 MA. 605.00	MODEL C-1581:	125-325 VDC, 0-1500 MA. 575.00
MODEL C-1582M:	325-525 VDC, 0-1500 MA. 680.00	MODEL C-1582:	325-525 VDC, 0-1500 MA. 650.00

800 MA MODELS **NEED ONLY 7" OF PANEL HEIGHT!**

(metered)		(unmetered)	
MODEL C-880M:	0-200 VDC, 0-800 MA. 370.00	MODEL C-880:	0-200 VDC, 0-800 MA. . 340.00
MODEL C-881M:	125-325 VDC, 0-800 MA. 345.00	MODEL C-881:	125-325 VDC, 0-800 MA. . 315.00
MODEL C-882M:	325-525 VDC, 0-800 MA. 390.00	MODEL C-882:	325-525 VDC, 0-800 MA. . 360.00



400 MA MODELS **NEED ONLY 5¼" OF PANEL HEIGHT!**

(metered)		(unmetered)	
MODEL C-480M:	0-200 VDC, 0-400 MA. 289.50	MODEL C-480:	0-200 VDC, 0-400 MA. . 259.50
MODEL C-481M:	125-325 VDC, 0-400 MA. 274.50	MODEL C-481:	125-325 VDC, 0-400 MA. . 244.50
MODEL C-482M:	325-525 VDC, 0-400 MA. 289.50	MODEL C-482:	325-525 VDC, 0-400 MA. . 259.50

200 MA MODELS **NEED ONLY 5¼" OF PANEL HEIGHT!**

(metered)		(unmetered)	
MODEL C-280M:	0-200 VDC, 0-200 MA. 214.50	MODEL C-280:	0-200 VDC, 0-200 MA. . 184.50
MODEL C-281M:	125-325 VDC, 0-200 MA. 189.50	MODEL C-281:	125-325 VDC, 0-200 MA. . 159.50
MODEL C-282M:	325-525 VDC, 0-200 MA. 199.50	MODEL C-282:	325-525 VDC, 0-200 MA. . 169.50

For all power supply needs through 1.5 amperes:

LAMBDA COM-PAK® POWER SUPPLIES

Less space! Improved performance!

Long, trouble-free service!

Transient free output!

Fills the need for compact, regulated DC power supplies. Economy of panel space, functional simplicity, new quick-service features.

Wiring, tubes and other components readily accessible. You can reach them easily, service them fast.

400 MA, 800 MA, and 1.5 ampere models include new, high-efficiency, long-life, hermetically-sealed semi-conductor rectifiers. All Com-Pak models are constructed with hermetically-sealed magnetic components and capacitors for long trouble-free service.

Condensed Data

LINE REGULATION	Better than 0.15% or 0. Volt, whichever is greater.
LOAD REGULATION	Better than 0.25% or 0. Volt, whichever is greater.
INTERNAL IMPEDANCE	
C- 200 Series	Less than 6 ohms.
C- 400 Series	Less than 3 ohms.
C- 800 Series	Less than 1.5 ohms.
C-1500 Series	Less than 0.75 ohms.
RIPPLE AND NOISE	Less than 3 millivolts rms.
POLARITY	Either positive or negative may be grounded.
AMBIENT TEMPERATURE	Continuous duty at full load up to 50°C (122°F) ambient.
AC OUTPUT (unregulated)	6.5 VAC (at 115 VAC Input)
C- 200 Series	10 AMP
C- 400 Series	15 AMP
C- 800 Series	20 AMP
C-1500 Series	30 AMP
AC INPUT	105-125 VAC, 50-400 CPS
OVERLOAD PROTECTION	AC and DC fuses; built-in blown-fuse indicators.

SEND FOR COMPLETE 32-PAGE CATALOG

Contains full information and specifications on Lambda's full line of transistor-regulated and tube-regulated power supplies.

ALL LAMBDA POWER SUPPLIES ARE GUARANTEED FOR FIVE YEARS.

LAMBDA ELECTRONICS CORP.

11-11 131 Street, College Point 56, N. Y.

CIRCLE 45 ON READER SERVICE CARD

. . . *Italian chromatograph, Fractomatic 110, debuts* . . .

with slits around the rim by pressing a registering ring against the piston. The slits alternately pass and interpret the light beams of three photocells set above the wheel. For every 5 mm movement forward (or backward) of the piston, the cells send out pulses (the sequence of the pulses depends on which way the piston is moving) which advance (or retract) a digital readout one figure.

• **Process instruments too**—For process users, one of the new products on display was the Fractomatic 110, an industrial chromatograph built by Carlo Erba Co. for continuous automatic plant stream monitoring. It is based on the absorption or partition method of gas chromatography. Main parts: an analyzer unit, control unit, and recording unit.

Continuing the electronic trend, the instrument has a high sensitivity electronic controller to maintain constant temperature of the metallic cylinder on which the chromatographic spiral shaped column is mounted. And the detector has a transistorized dc power supply.

The Fractomatic 110 can be equipped with a special calculating unit so that the chromatograph can be inserted in the automatic control loop of a process. This additional unit contains an electronic integrator and four memory complexes which provide continuous visible indication and electrical signals related to the concentration of four components chosen from the mixture to be analyzed. The electrical signals can be fed to conventional regulators, closing the loop.

• **Sedimentation scale**—Another electronic instrument displayed by Erba was a sedimentation scale for granulometric analysis. The device, made under a license from the German company Sartorious-Werke A.G., automatically records the weight increase of sediment deposited on a scale plate as a function of time. The resulting plot shows the distribution of sediment within one micron.

To date, German and U. S. manufacturers have supplied the bulk of control equipment used in Italy, with U. S. makers holding an edge because many users feel German control is too expensive. But the spurt of new activity in Italy's own control industry seems sure to slice the share of the market held by foreign producers.

—Gene Di Raimondo
McGraw-Hill World News

Looking for the newest, most complete line of General Purpose Switches?

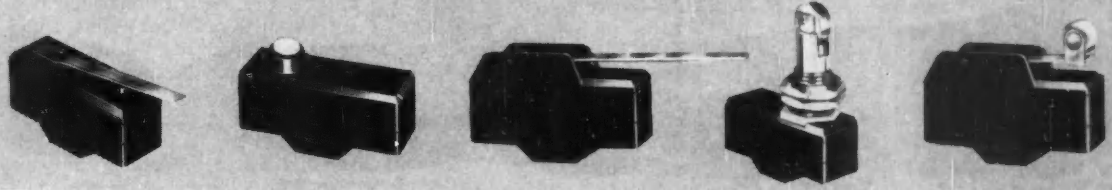
Acro's newly designed model B and F switches will meet your toughest electrical and mechanical requirements

Just check Acro's brand new features!

1. ***NEW!*** Acro's clip-on cover construction, which requires no drilling or pinning, eliminates bakelite dust particles from contaminating the contacts.
2. ***NEW!*** Acro's famous rolling spring principle insures low minimized contact bounce. This gives you high horsepower rating and longer electrical life.
3. ***NEW!*** Up to 21 amp, 2 HP in the F series!
4. ***NEW!*** Moulded-in terminal posts, with blind tap holes, keep out dust and contamination.
5. ***NEW!*** And now Acro offers the most complete line of actuators. Shown are just 10 of the complete series.

model B switches

U.L. Approved 15 AMP 120-240-480 V.A.C. ½ AMP, 120 V.D.C., ¼ AMP, 240 V.D.C.
For detailed specifications and prices write for Catalog B.



BRD2-5L-1S
Leaf Actuator
Operating Characteristics

Operating force	5 oz. max.
Release force	½ oz. min.
Pretravel	.156 max.
Overtravel	1/32 min.
Movement diff.	.050 max.

BRD2-70-1S
Short Overtravel Plunger
Operating Characteristics

Operating force ..	9-13 oz.
Release force ..	4 oz. min.
Pretravel ..	.010-.025
Overtravel	1/16 min.
Movement diff.	.003 max.

BRD2-LW8-1S
Overtravel Leaf Actuator (long)
Operating Characteristics

Operating force	2½ oz. max.
Release force	½ oz. min.
Pretravel	9/32-13/32
Overtravel	.187 min.
Movement diff.	.016-.078

BRD2-24P-1S
Roller Panel Mount
Operating Characteristics

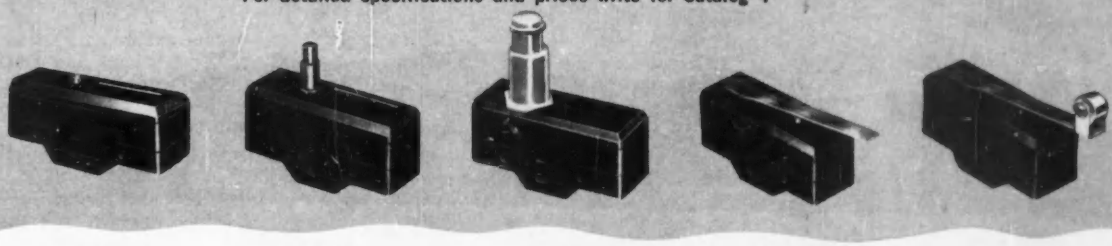
Operating force ..	9-13 oz.
Release force ..	4 oz. min.
Pretravel ..	.010-.025
Overtravel	.140 min.
Movement diff. .	.003 max.

BRD2-LW228-1S
Overtravel Roller Leaf Actuator (short)
Operating Characteristics

Operating force	6 oz. max.
Release force	1½ oz. min.
Pretravel	.045-.140
Overtravel	.080 min.
Movement diff.	.006-.031

model F

U.L. Approved 21 Amp, 120-240-480 V.A.C., 1 H.P. 120 V.A.C., 2 H.P. 240 V.A.C.
For detailed specifications and prices write for Catalog F



FAD2-1A-1S
Pin Actuator
Operating Characteristics

Operating force	10-18 oz.
Release force ..	6 oz. min.
Pretravel	.050 max.
Overtravel	.010 min.
Movement diff.	.0075 max.

FAD2-10-1S
Long Overtravel Plunger
Operating Characteristics

Operating force	10-18 oz.
Release force ..	6 oz. min.
Pretravel	.050 max.
Overtravel	1/16 min.
Movement diff.	.0075 max.

FAD2-3P-1S
Large Overtravel Plunger
Operating Characteristics

Operating force	10-18 oz.
Release force ..	6 oz. min.
Pretravel	.050 max.
Overtravel	7/32 min.
Movement diff.	.0075 max.

FAD2-5L-1S
Leaf Actuator
Operating Characteristics

Operating force	9 oz. max.
Release force ..	1 oz. min.
Pretravel	11/32 max.
Overtravel	1/32 min.
Movement diff.	.065 max.

FAD2-2M-1S
Roller Leaf Actuator
Operating Characteristics

Operating force	9 oz. max.
Release force ..	1 oz. min.
Pretravel	11/32 max.
Overtravel	1/32 min.
Movement diff.	.065 max.

for detailed specifications and prices write for catalogs "B" and "F".

Free engineering service. Our engineers will be happy to pit their professional experience against your tough switching problem. Just tell us what it is . . . we'll recommend ways to solve it. No obligation, of course.

RELAYS ACRO SWITCHES

"OUR 21st YEAR"

ACRO DIVISION Robertshaw

COLUMBUS 16, OHIO

Optical Versus Magnetic Reading

How should documents be read by machine—optically or magnetically? A small company with an optical reader tackles the giants and magnetic readers.

NEEDHAM, MASS.—
Input preparation, the big problem in automatic data processing, is on the verge of solution. Optical and magnetic readers are now available to convert written information to punched cards, punched tape, or magnetic tape for electronic processing. The big question facing users of data processing is which equipment to choose—magnetic or optical?

The Farrington Mfg. Co., small compared to the standards of U. S. big corporations, has the U.S. optical reader business to itself. Opposing it with magnetic readers is some imposing competition: IBM, Burroughs, National Cash Register, and General Electric. Still, Farrington is basing its hopes for sensational growth in the next five years on the optical reader.

• **Started in an attic**—Farrington's reader is the brainchild of David Shepard, who first got the idea while working in a federal government agency and watching the mountain of paperwork being read by fellow employees. He started tinkering in his attic, trying to build a machine that would read with an electronic flying spot scanner—much the way a television picture is reproduced. Striving to improve the reliability of his reading machine, Shepard switched to an electromechanical optical scanner. Although the optical scan was slower, it operated virtually trouble-free, required little maintenance, and was economic to build.

In 1954 he built the first working optical reader to read travelers checks for the Bank of America. Stanford Research Institute was to build the paper handling equipment and integrate the reader into a complete data processing system.

Disaster then struck the optical reader. The dateline area on the checks was just above the numbers which the reader had to recognize. When check writers scrawled their locations across the numbers, the optical reader went blind. Faced with this dilemma, and fearing other possible interferences, Stanford Research Institute engineers took an obvious way out: switched to magnetic reading which worked (CtE, July 1958, p. 79).

Calamities compounded for the optical reader. Because of the success of the Bank of America travelers check processor, the American Banking Association decided to adopt magnetic characters as the standard for check processing. With ABA standardization assured, the big office machine makers developed magnetic reading equipment and started to publicize the new gear throughout the country.

• **Optics snap back** – Meanwhile, Shepard continued to work on optical readers at his small Intelligent Machines Research Corp. in Arlington, Va. He solved the interference problem by using a glossy ink for the numbers, and then reading the gloss rather than the numbers themselves. In 1955 he sold a machine to Readers Digest Association to process orders received by its book club.

The Readers Digest installation gave new heart to supporters of optical readers. It worked without a hitch (and is still working, paying for itself every six months).

At Readers Digest Shepard machine reads names and addresses from book orders, codes them, and puts them on punched cards. Before the unit was installed, the Digest had to hire and train 150 key-punch operators twice a year to handle its seasonal book business.

Meanwhile, IMR had aroused the interest of Farrington which took the optical reader to oil companies as an obvious means of handling credit card inputs. A special version of the unit was developed and marketed under the trade name of Scandex. It will read the account number on the credit slip received from a service station and convert the invoice into a punched card ready for further processing at rates up to 180 per min. Scandex has slowly won the approval of the oil industry; 16 units have been sold.

• **Enter Farrington**—In 1958 the investment company which owned Farrington Mfg. Co., maker of many of the credit card imprinters used by oil companies, became dissatisfied with the way company sales had plateaued.

THE ¾" POT — THAT FITS A ¾" SLOT

DAYSTROM'S NEW MULTIPOT® ELIMINATES
PROTRUDING SIDE TERMINALS → 
PROVIDES 25% BETTER PACKAGING DENSITY

For general test equipment and computer applications, there's no beating the low cost and easy access of Daystrom's miniature Series 450 MULTIPOT®. The rear-mounted terminals of this 10-turn potentiometer cut assembly time, reduce space requirements . . . and you pay no premium for miniaturization.

The Series 450 offers standard resistance from 1K to 250K . . . has a 2½-watt power rating . . . operates from −65°C to +100°C.

For complete specifications, write for Data File CE-861-2

Openings Exist for Qualified Engineers

DAYSTROM PACIFIC
a division of DAYSTROM, INC.
9320 LINCOLN BLVD., LOS ANGELES 45, CALIFORNIA
potentiometers / gyro instruments / airborne systems

CIRCLE 49 ON READER SERVICE CARD

To do something about it, Farrington's top management was reorganized, and young William Tetrick was brought in as executive vice-president to be groomed for the presidency.

One of Tetrick's first steps after becoming president early in 1959 was to buy Intelligent Machines Research because it was a natural extension of Farrington's interest in credit cards. In addition, Farrington's former management had built too big a plant at Needham; since IMR needed productive capacity to get volume production of its optical reader, the acquisition promised to improve the utilization of Farrington's facility. Manufacture of optical readers will begin in Needham at the start of 1960. Shepard, the optical-reader pioneer joined Farrington as vice-president in charge of research and development.

• **Optical explosion** – Tetrick has geared Farrington's substantial plans for growth to the optical reader. The company's 1959 sales ran a little over $11 million. Tetrick expects 1960 sales will hit $20 to $22 million (that includes all of the other Farrington products: credit cards, credit card imprinters, display cases, and printed circuits). Data processing sales are estimated to run only $5 million in 1960, but tetrick expects data processing sales to double each year for the next three years!

One thing that encourages Tetrick's staff is that the builders of magnetic readers have now run into troubles which seem every bit as bad as those that Shepherd ran into with his first optical check reader. Magnetic readers require that the magnetic numerals be printed with an accuracy that many commercial printers cannot now meet. The printer has to keep the amount of ferrites in the magnetic inked figures within 5 percent, something not too easy on most presses. And holding tolerances to a few thousandths of an inch is equally troublesome.

• **Proved applications**–The almost clear field in optical reading (National Cash Register Co. now has an optical reader too) and the obstacles in the magnetic reader add up to a bright market picture in the eyes of Farrington's executives. Executive Vice-President Russ Harrell says "You can't name a single application of automatic data processing in which the optical reader won't prove practical."

Probably the fastest growing use of optical readers (outside the oil company credit slips) has been in cash accounting. The machines read the receipts returned with monthly pay-

ments and prepare punched cards of the amount and amount paid. New York Telephone Co. may buy as many as 20 of the machines for this purpose. Cost: about $25,000 each. But the market extends to life insurance and loan companies and utilities.

In banking operations the machines can be used to handle large volume check disbursements such as dividend payments for a big corporation or pay checks. In addition, the machine can be designed to spot checks that are returned with changes of address.

The American Telephone and Telegraph Co. is using an optical reader to help keep track of proxies for stockholder meetings. AT&T already has four machines, has one more on order. The machines read returned proxies to determine which of the company's huge number of shareholders have not returned proxies so that second notices can be sent to those not replying.

• **New applications**–Some of the newer applications of optical readers have been getting more publicity than the well proven ones.

▶ Item: Farrington has built an automatic reading machine for the Air Force that will read a page of hard copy and convert it to punched tape which can run a teletype machine. The Air Force is interested in the machine to mechanize its giant communications operation.

▶ Item: the Post Office has a prototype optical reader that can read typed addresses on mail for sorting. Farrington is now building an improved version of the machine.

▶ Item: Arizona Public Service is currently testing a prototype system for aiding utility meter readers. In most utilities, after reading a meter, the utility's field representative writes the reading down; later it is copied and put on punched cards. Frequently, however, the field man's writing is so bad that the reading is not decipherable. With Farrington's prototype system, the reader will imprint the readings with a portable (weighing 4 pounds) device on a tape prepared in the utility's computer. When this tape is returned to the central office, the optical reader will scan it, sending the new reading into the computer which will then bill the customer.

• **Paper work automation** – Some new applications of readers still on the drawing boards promise a whole revolution in office paper work. For example, Farrington researchers have developed a system for printing airline tickets quickly so they can be read by an optical reader to prepare account-

ing statements for the airline. And a joint project with the National Retail Merchants Association may result in a new method of recording purchases at point of sale.

• **Place for both**—Farrington has no delusions about optical readers taking over the field completely. Both Harrell and Tetrick point out that too much time and money has already been invested in magnetic readers for their suppliers to drop them. Manufacturers of magnetic readers, say the Farrington executives, will solve their problems just as Shepard solved his in the optical reader.

Tetrick is so sure of this that he has the research team headed by Shepard working on a magnetic reader which will read magnetic figures the same way the optical reader reads ordinary printing. The device should be tested in 1960.

—Lewis H. Young

Intec Imports Ideas, Produces Hardware

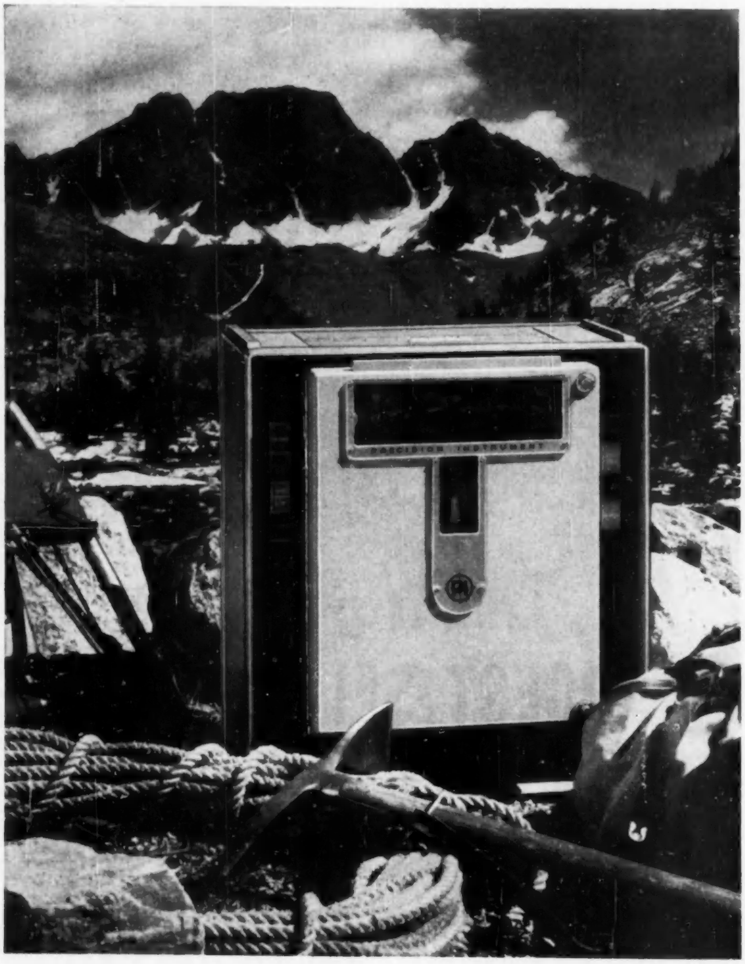
MINEOLA, N. Y.—

Instrument ideas developed in Europe are being imported to Long Island and converted to production hardware by the International Electronics Corp., a relatively new company with king-sized growth plans. After a slow start in 1956, Intec has more than doubled its sales in each succeeding year, expects to triple 1959 sales of $3.3 million in 1960.

Intec got its start when executives at Airborne Instruments Laboratory became intrigued with developments they heard about in Europe. AIL decided to set up a subsidiary, completely apart from AIL and its heavily military-oriented business, to market such ideas.

The company was formed in 1956 with a truly international flavor. Technical support was to be supplied by AIL and Compagnie de Generale de Telegraphie Sans Fil (CSF) in Paris. Additional financial backing came from The American Research and Development Company (The Laurence Rockefeller organization), J. P. Morgan & Company (now the Morgan Guaranty Trust Company), and the Bank of Paris.

In 1956 the company made its American debut by renting a portable TV camera to the Columbia Broadcasting System for coverage of the Democratic and Republican national conventions. The battery-powered cameras, a CSF design, worked perfectly, but the power requirements were so large that the cameras had an insatiable demand for batteries. When the conventions ended, Intec returned the cameras (CP-102) to CSF's re-



WHAT'S NEW

. . . for 1960, new products may triple Intec's sales . . .

search laboratories. Total sales in 1956 added up to a puny $10,000. The CP-102 has since been completely redeveloped with a much lower power requirement. Today it is a formidable contender in the low cost portable camera business.

Intec's next European import, however, turned out much better, finally started the company growing. The development was the "Frenchecon", a scan conversion tube. This device, also developed by CSF laboratories, converts electronic information such as that stemming from radar to a bright TV display. It can receive information at one rate, and turn it out at another. The tube has built-in storage or memory capability.

The first U. S. scan conversion gear (called a video transformation tube by Intec) was tested by the Civil Aeronautics Administration at its Indianapolis Technical Center. It won a resounding approval and CAA ordered the tube for control towers at Indianapolis, Washington (D.C.), and Idlewild (New York City) airports. Today, the Federal Aviation Agency (successor organization to CAA) has installed 50 Intec video transformation tubes. And the Navy is buying Intec-built radar-to-television scan conversion systems for its Radar Air Traffic Control Centers.

At the end of 1959, Intec purchased Westbury Electronics to provide additional production capacity. And Intec buttressed its product line by adding the Westbury line of TV equipment and magnetic amplifiers. In 1959, component sales reached over $300,000.

Intec's sales goal for 1960 is $10 million. To reach this, the company is counting on continued sales of its scan conversion tube systems and tubes, its magnetic amplifier line, and community antenna systems which Westbury Electronics has made. In addition, Intec has some new products to offer: an accurate direct reading, transistorized radio altimeter designed primarily for helicopters, moving target indicator tubes, and dual and triple frequency diversity radar which combines a short and long range radar in one system, for greater reliability and more complete coverage.

To put foreign developments on the U. S. market, Intec first has to study the engineering differences, then redesigns for compatibility, "Americanizes", and operates the equipment in a test or operational environment.

GPE Shuffles; 4 Divisions Emerge in New Setup

General Precision Equipment Corp. has responded to the increased emphasis on complete systems procurement through the means of a new organizational lineup. Formerly the firm could not bid on systems contracts except through single subsidiaries; GPE served only as a holding company.

Now its four principal units are included in a new company, General Precision, Inc., which can bid based on the combined capabilities of its four divisions: General Precision Laboratory (Pleasantville, N. Y.), Kearfott Co. (Little Falls, N. J.), Librascope (Glendale, Calif.), and Link Aviation (Binghamton, N. Y.).

GPE is also aiming for improvements through greater efficiency, flexibility, and standardization as result of the management consolidation. GPE's electronics business has increased to such an extent that the 1960 sales of the four divisions included in the new company are expected to equal this year's total GPE sales (forecasted at $200 million). Estimated 1959 sales for the four-division group are $177.3 million.

Interesting to note in the complex GPE scheme is the growing interest of The Martin Co. (primarily a missile maker). Latest reports show that Martin now holds 183,700 shares or 16.3 percent of GPE ownership. This shows an increase of almost 17 percent of the last reported holdings (Oct. 10). Martin is GPE's largest single stockholder; it is also one of GPE's prime customers.

GPE shuffling is also going on in England where the British subsidiary of the company, Air Trainers Link Ltd., has been renamed General Precision Systems Ltd. Outlook: an upcoming push by GPE to sell its GPL-designed air traffic control system (prototypes ordered by the Federal Aviation Agency) in Europe and the Commonwealth markets. A special ATC division has been set up to be headed by British Overseas Airways Corp.'s former control and navigation superintendent, Edward Pike.

Refinancing has raised the issued share capital from $910,000 to $1.7 million. GPE retains 53 percent control of the company, but 25 percent of the remainder has been acquired by Decca Radar Ltd. Their role: provide the radar and display systems for the GPS ATC. Flight simulation equip-

ment is continued under license from Link Aviation, and the company's industrial controls division, still in its infancy, will supplement its homegrown development through manufacturing licenses from GPE.

Russian-Capitalist Trade Increases 16 Percent

Soviet trade with the capitalist countries showed a 16 percent increase in physical volume in 1958 according to figures recently released by the Russian Embassy in Washington Lower prices limited the dollar increase to 3.7 percent, but the overall total of trade turnover was 9.076 billion rubles. At the official rate of exchange (4 rubles/dollar) this is $2.269 billion. The more realistic tourist rate (10 rubles/dollar) still makes it nearly $908 million.

Britain still holds a top position on Russian trading lists, even though trade turnover decreased by about 25 percent from 1957. Most of this decline was due to lower prices. During 1958 the USSR placed a 160 million ruble order for a complete tire factory and a 45 million ruble one for the equipment for an acetate rayon factory. U. S. trade with Russia increased 18.3 percent, remained insignificant.

A significant characteristic of Soviet exports composition was the substantial increase in sales of machinery and equipment—from 4.6 of the total in 1956 to 14.6 percent in 1958. The bulk of these shipments was made up of equipment for complete factories in economically underdeveloped countries. Exports of machinery in 1958 almost equalled imports.

Largest increase (295 percent) was in trade with the United Arab Republic (Syrian Region). Trade with India was up 50 percent. A major part of this increase was in complete sets of equipment such as for the Bhilai Iron and Steel Works.

French trade with Russia increased by almost one-half with a decided shift in composition marked by an increase in Soviet exports of machinery and equipment. West Germany exported 16.5 percent more to Russia in 1958; machinery shipments were up 60 percent.

UK Eyes Instrument Show In Moscow in 1960

—LONDON

British scientific instrument makers are hoping to boost sales to Russia by holding an exhibition in Moscow, probably in the second half of next year. The Moscow All Union Chamber of Commerce invited the British Scientific Instrument Manufacturers'

Association (SIMA) to send a delegation to the Russian capital to explore possibilities for a trade show to be accompanied by demonstrations and lectures.

The three-man team, representing some 180 SIMA members, spent several days in Moscow, but after their return no official report was available as this issue went to press. However, a reliable source at SIMA says that the mission was a success and that an agreement in principle to hold the show had been reached.

What this exhibit will do to British Instrument exports to the USSR is anybody's guess; such trade follows a political rather than a commercial pattern. Shipments of these goods in 1958 totaled $500,000. Most British manufacturers feel that Russians mean business and quote the complete tire factory and chemical plant (see above story) as examples. They point out also that it was the Russians who issued the invitation.

SIMA has stated that 36 manufacturers in various fields covered by the association already have said they would participate if the show does come off. SIMA states that recent trade with USSR in instruments has led it to believe that "a far more substantial business could be built up." The Russians, says SIMA, "like the quality and special, often unique, scope of our instruments".

Electrosnap Merges Into Controls Co. of America

Chicago precision switch manufacturer, Electrosnap Corp., has been absorbed by Controls Co. of America, electrical controls and control systems, electric motors, and miniature electrical products maker with offices in Schiller Park, Ill.

The merger which will make no change in the number of shares of common stock held by Controls Co. owners. However, each five shares of Electrosnap stock will be converted into six shares of Controls Co. common. The needed stockholder approval was to be voted on at the end of December.

Litton Acquires Top Hand At Swedish Register Maker

Svenska Dataresgister AB, Stockholm, Sweden, will now be controlled by Litton Industries, Inc. Litton also obtained full ownership of two distributing companies for Svenska's

products, which are cash registers and point of sale recording equipment under the Sweda brand name.

The marketing companies are Sweda Cash Register, Inc., a Chicago firm which is the American distributor, and Sweda Registrierkassem, AG of Zurich, Switzerland. They will be administered through Litton's Monroe Calculating Machine Co. Div.

Terms of the sale of the majority interest to the Beverly Hills-based company were not revealed, but Litton expects that it will add $10 million a year to Monroe's sales.

Leach Buys Part Of Pendar, Inc.

The Electronics Div. of Pendar, Inc., Van Nuys, Calif., will now be integrated with the Relay Div. of the Leach Corp. The Los Angeles electronics firm recently purchased the unit which makes static switching, timing, and annunciator devices. The parent Pendar company will retain its pushbutton switch business.

Houston Fearless Adds Federal Machine Tool

Federal Machine Tool Co. of Boston has been acquired by Houston Fearless Corp. in a deal involving payment in Houston Fearless common stock. Federal manufactures electronic components, process control equipment, and microwave gear. Precision tooling and design is also continued under the new ownership. Federal will retain its name and become a division of the Los Angeles corporation.

Harris-Intertype Furthers Electronics Plunge

Long known mainly for printing equipment, Harris-Intertype Corp. has deepened its investment in the electronics field with its purchase of Polytechnic Research and Development Co. from the Polytechnic Institute of Brooklyn.

PRD, a leading producer of microwave test equipment, was founded during World War II as an outgrowth of new developments by the electrical engineering department at Brooklyn Poly. It worked closely with the Radiation Laboratories at MIT (the first Poly group was the Microwave Research Institute, now a college department).

PRD will be operated as a subsidiary of Harris with the intention


KEY
TO
MISSILE
OPERATION
MARTIN

of maintaining close relationships between the company and the school. The acquisition puts Harris much further in the electronics business; the purchase of Gates Radio Co. two years ago started the diversification move from the printing industry alone.

Fairfield Gains Cove Facilities Through Merger

A merger has been consummated between Fairfield Engineering Corp. of Springdale, Conn., and Cove Industries, Inc., of Norwalk, Conn. Fairfield acquires Cove's assets in exchange for Fairfield stock, according to the terms of the agreement.

Fairfield began operations in 1955 making magamps for thyratron control and produced the first magnetic control for silicon control rectifiers. Cove, barely three years old, does subcontract work in fabrication, packaging, and assembly of several electronic systems and also manufactures components. The addition of Cove is aimed at increasing Fairfield's production efficiency.

Beckman Gets Two For $130,000

As a product line expansion move, Beckman Instruments, Inc., has acquired Harold Kruger Instruments of San Gabriel, Calif., and Tool-Lab, Inc., of Escondido, Calif. Initial cash investment for both companies was approximately $130,000.

Kruger's products (to be added to Beckman's Scientific and Process Instruments Div. line) include chemical analysis equipment, air pollution monitoring instruments, mercury vapor detectors, and metering pumps. The Fullerton, Calif., purchaser will assign manufacture and sales of Tool-Lab's electric meters to its Helipot Div.

New Consulting Firm Offers EDP Counseling

Charles W. Adams Associates, Inc., Medford, Mass., is a new consulting firm offering advice to companies seeking aid in applying electronic data processing systems. The Adams group will conduct a survey of a company's EDP application; the end product of such a survey is a complete status report. If desired, however, Adams can go further and assume responsibility for developing and installing the EDP procedure, including programming, forms, and instruction.

IMPORTANT MOVES BY KEY PEOPLE

Instrument, Computer Man New IRE President

New president of the Institute of Radio Engineers is Dr. Ronald F. McFarlan, a consultant to the Datamatic Div. of Minneapolis-Honeywell and to the Raytheon Co. Announcement of the election came at IRE's board of directors meeting held in New York City recently.

Dr. McFarlan's early work was in the fields of X-ray diffraction and scattering, ultraviolet spectroscopy, electronic instrument design, and navigation. He has managed projects dealing with digital computers, radar, automatic guidance and control, microwave communication, sonar echo ranging, and depth sounding equipment.

Also announced at the board meeting were the recipients of several IRE awards including two important honors to control leaders. Dr. Harry Nyquist received the 1960 Medal of Honor, and Dr. J. A. Rajchman the 1960 Morris Liebman Memorial Prize.

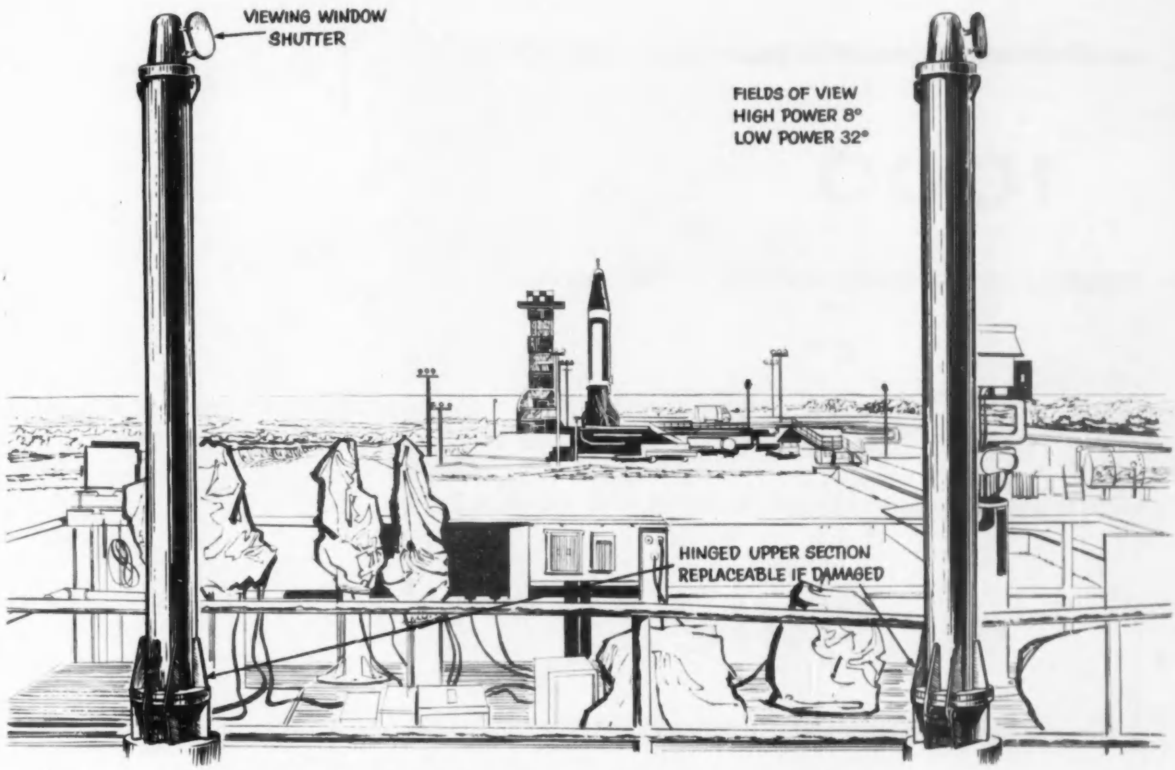
Dr. Nyquist's award was made "for fundamental contributions to a quantitative understanding of thermal noise, data transmission, and negative feedback". He divides his time between The W. L. Maxson Corp., Stavid Engineering, Inc., and Bell Telephone Labs. Dr. Rajchman was cited "for contributions to the development of magnetic devices for information processing". He is a member of RCA's research staff for solid-state computing devices and digital systems.

Brubaker Quits As Telecomputing V. P.

George Brubaker, founder of Brubaker Electronics, Inc., in 1950 and president of Telecomputing Corp. after his company's merger, has resigned as vice-president of marketing and board member of the Los Angeles electronics company. He had stepped down from the top post in a previous realignment.

West coast sources say that Brubaker left after differences with TC's president William Whittaker.

The apparent upset at Telecomputing showed up in the investment market last month when TC's recent stock issue, which came out at $13, dropped 25 percent—a surprising performance



Cape Canaveral count-downs get Kollmorgen close-ups

What happens on the pads at Cape Canaveral is subject to the continuous close scrutiny of experts thanks to Kollmorgen bunkerscopes. During launching operations and static tests the trained observer sees exact detail in his choice of two magnifications and in true color, with complete safety even in cases of power failure.

Bunkerscopes by Kollmorgen require virtually no maintenance and are built to withstand blast forces such as may be expected around missile launching sites. They are easy to operate, even by untrained personnel, and can quickly be adapted to photography and television use.

These instruments are typical of Kollmorgen experience with remote viewing and inspection equipment, wall periscopes, underwater periscopes, micro-photo periscopes, continuous strip fuel-inspection cameras and other optical systems employing mechanical and electronic skills. In this field Kollmorgen is foremost, having served both industry and defense for nearly half a century.

If you are interested we would like to send you our new illustrated facilities brochure. Just write us a note on your company letterhead.

KOLLMORGEN
optical corporation
NORTHAMPTON, MASSACHUSETTS

NUCLEAR REMOTE VIEWING EQUIPMENT • SUBMARINE PERISCOPES • OPTICS • BORESCOPES • MOTION PICTURE AND TELEVISION LENSES • PRECISION OPTICAL INSPECTION AND ALIGNMENT DEVICES • ELECTRONIC CONTROLS AND COMPONENTS • NAVIGATIONAL AIDS

WESTERN TECHNICAL REPRESENTATIVES —
COSTELLO & COMPANY, LOS ANGELES, CALIFORNIA.

for a space age electronics company. TC officials hope to improve the confidence of the market when they appear before LA Security Analysts on February 25. They point to recent acquisitions (Monrovia Aviation, Frank R. Cook Co., and Summit Electronics) as evidence of the company's growing strength.

Beckman's Bishop to Head Textron Electronics

LOS ANGELES—

John F. Bishop, general manager of the Systems Div., Beckman Instruments, Inc. moved to Textron Electronics, January 1, to become executive vice-president and chief operating officer of the Textron subsidiary. Bishop's appointment is TE's first step in forming a corporate staff to provide overall management guidance for a broad-based electronics company.

Textron Electronics was formed in May 1959 with one division, MB Electronics, maker of electronics and electromechanical vibration test systems and formerly a division of parent company Textron. In September TE acquired Globe Electronics, communications equipment manufacturer. TE's third quarter sales, the first full quarter of operations, amounted to $4,744,000.

One of Bishop's main jobs at TE will be filling out TE's product line by acquisition of additional companies in the electronics, instrumentation, and control fields.

Also joining TE, as vice-president for marketing, is Mark Howlett, now marketing manager at Beckman's Process Instruments Div.

Other Important Moves

Joseph Carlstein has moved up to chief engineer for the Ketay Dept. of the Norden Div., United Aircraft Corp. With the Commack, N. Y., unit since 1953, Carlstein has held several engineering positions; last one was supervisor of development engineering.

J. S. Pitchford, recently retired from the Air Force as colonel, has been appointed vice-president in charge of engineering at Benson-Lehner Corp., Santa Monica, Calif. He'll direct B-L's engineering department with emphasis on new product development.

Dr. George Wertwijn has joined U. S. Transistor Corp. as chief engineer. He was formerly division chief

FISCHER & PORTER

INSTRUMENTS THAT MEASURE AND CONTROL TEMPERATURE, PRESSURE, FLOW, &c., &c., &c.
have established and maintained their reputation for superiority against all competitors through the years and are in increasing demand. As in the past, it is the unalterable DETERMINATION OF THE HOUSE TO SEND OUT NOTHING BUT WHAT IS OF

THE HIGHEST POSSIBLE QUALITY

THE HANDIEST GUIDE TO THE VARIOUS AND SUNDRY METHODS PRESENTLY AVAILABLE FOR MEASURING FLOW

It has been our pleasure and profit over the years to aid and assist divers engineers in the estimable task of selecting the one—nay, the *only* device best suited to measuring a given flow. But truly, the years have added, the devices have multiplied, and the task of selection has grown ever more complex. As a result, the "handy" guides, so reminiscent of an earlier day have grown less handy all the time. Let us see how handy we can be.

LESSON I

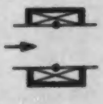
There are but four major types of flowmeters.

1. VARIABLE-AREA (ROTAMETERS)

2. VARIABLE HEAD (ORIFICES, VENTURIS & CO.)

3. INTEGRATING (TURBINE)

4. OBSTRUCTIONLESS (MAGNETIC)



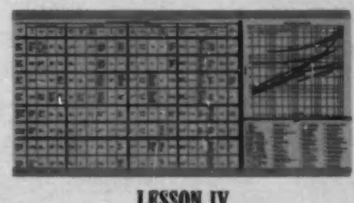
LESSON II

In order to be as handy as possible, we shall limit our discussion of the advantages of the four basic types to a single characteristic benefit.

1. Variable-Area: linear scale
2. Variable Head: flexibility
3. Integrating: accuracy
4. Obstructionless: obstructionless

LESSON III

The lesson to be learned may well be that there is a definite limit to just how "handy" one can be . . . and still serve as a guide. Six pages hold the record at present. We call the guide Bulletin 91-119, but others have called it the first practical map ever published to the land of flowmetering.



LESSON IV

There are those who philosophically oppose all "handy" guides. If you are among that group, we can only state that we make them all . . . every one of the four major types. A call to our technical assistance group will bring you a firm recommendation unencumbered by bias or prejudice.

THE JUSTLY CELEBRATED

MAGNETIC FLOWMETER

OF FISCHER & PORTER

one of the very best flow instruments ever invented

A clear length of pipe that accurately measures liquid flow by the invisible MAGNETIC FIELD!
SOMETHING NEW! Measures the flow of any liquid with a conductivity of no less than 0.1 micromho per centimeter.
Measures flow IN EITHER DIRECTION and without auxiliary equipment.
Handily provides full scale recording of ANY FLOW RATE from 1 to 30 feet per second at the TURN OF A DIAL

extends the range of accurate flowmetering to heretofore unbelievable limits!

YOUR ATTENTION INVITED!

of the Semiconductor Development Group of Zenith Radio Corp. and held a position in the transistor division of the N. V. Philips Lamp Works in the Netherlands. The new Syosett, N. Y., company has just started producing germanium alloy transistors.

Ralph E. Clarridge, who was a consultant with Taylor Instrument Co., is now manager of the measurements laboratory of the General Electric Instrument Dept., West Lynn, Mass. He was 20 years with Taylor, most recently as chief engineer and finally as staff consultant.

Jack Blair has become chief mechanical design engineer at North Atlantic Industries, Inc., Westbury, N. Y. Blair will direct work in line with the company's product diversification program. He was formerly with Reeves Instrument Corp.

Seymour Weiner has assumed the newly created position of product planning manager at Sperry Semiconductor. His responsibility is advanced planning for the S. Norwalk, Conn., division of Sperry Rand Corp.

Douglas K. Ridley has taken over as contract sales manager for automatic control equipment produced by the Philadelphia-based Brown Instruments Div. of Minneapolis-Honeywell Regulator Co. He'll also handle products of the other Honeywell Industrial Products Group units (Valve, Industrial Systems, Fall River (Mass.), Rubicon Instruments, and Heiland Divs.).

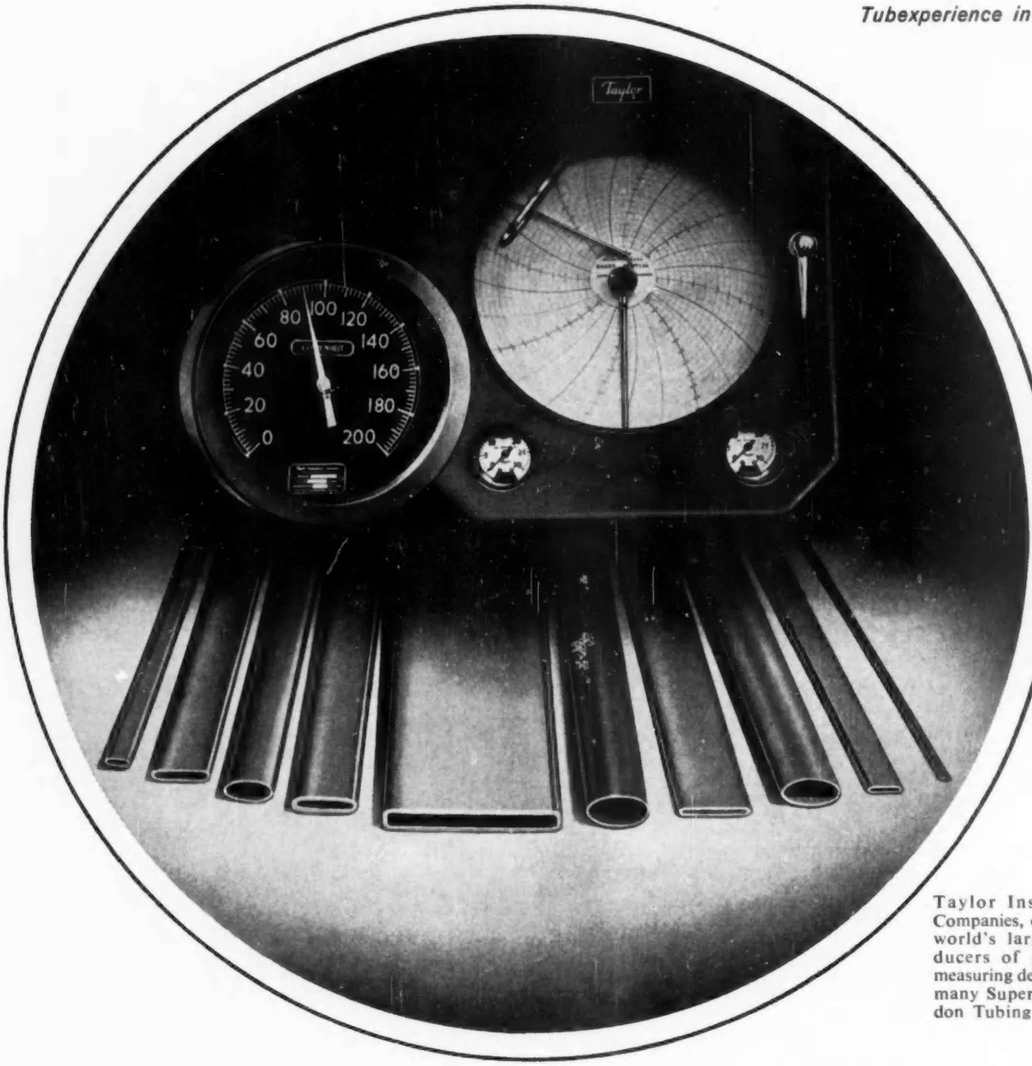
Irving P. Magasiny joins Schaevitz Engineering, Pennsauken, N. J., as director of engineering after 11 years with Philco Corp. and Tele-Dynamics.

G. Douglas Zimmerman will direct the activities of Canadian Curtiss-Wright Ltd. of Montreal as new executive vice-president and director. Zimmerman has been president of Fischer & Porter (Canada) Ltd. and C. P. Clare, Canada Ltd.

Ivar C. Peterson, formerly director of the Aerospace Industries Association's technical services, is now assistant to the president of Lear, Inc.

Charles D. Manhart, as new vice-president of Daystrom, Inc., will head the operations of the four divisions in the company's Defense Products Group (Electric, Military Electronics, Pacific, and Transicoil).

Tubexperience in action



Taylor Instrument Companies, one of the world's largest producers of precision measuring devices, uses many Superior Bourdon Tubing analyses.

℞ for accurate indication of pressure and temperature: Bourdon Tubing by Superior

Bourdon tubes with consistent spring rate and minimum set, drift and hysteresis are essential to precision measurement of pressure in modern indicating, recording and controlling instruments. The tubing from which they are made must be free of inclusions and seams, carburization or decarburization, rough or corroded surfaces, and variations in wall thickness. Superior Bourdon Tubing has the extra qualities that permit interchangeability of Bourdon elements in the field with maximum ease, simplify range changes, require only linkage adjustment.

Typical of the care exercised in the manufacture of Superior Bourdon Tubing is the use of weight control to check tubing dimensions. This fast, precision method of checking average wall or ID enables us to provide tubing with unusually high overall uniformity. No matter how many Bourdon elements you make from Superior tubing, you get a uniform deflection rate in every case.

Superior offers a wide range of analyses, including strain-hardened, precipitation-hardened and heat-treatable materials for the fabrication of Bourdon Tube elements. Write for a copy of Bulletin 41, giving detailed information. Write Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

CIRCLE 71 ON READER SERVICE CARD

BASIC BUILDING BLOCKS FROM KEARFOTT

ANALOG-TO-DIGITAL CONVERTERS

Kearfott's rugged shaft position-to-digital converters are resistant to high shock and vibration and high and low temperature environments. Ideally suited for missile applications, these converters are available for many uses, including latitude, longitude, azimuth or conventional angular shaft displacement conversion and decimal count conversion. Exclusive drum design provides large conversion capacity in smallest size. Combination counter converter assemblies for both visual and electrical readout also available.

TYPICAL CHARACTERISTICS

Kearfott Unit No.	P1241-11A
Code	Cyclic Binary
Range	0-32,768 (2^{15})
Bits per Revolution	16
Revolutions for Total Range	2,048
Volts D.C.	10.5
Current (ma.)	20
Inertia (gm. cm.^{2})	20
Unit Diameter (in.)	1⅞
Unit Length (in.)	3
Life	10^6 Revolutions or 10^3 hours
Static Torque (in.-oz.)	2 (break) 1 (running)
Weight (oz.)	5
Maximum Speed (RPM)	600

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT

20 SECOND SYNCHRO

This synchro, just one of a broad line offered by Kearfott, provides the extreme accuracy required in today's data transmission systems. Kearfott synchro resolvers enable system designers to achieve unusual accuracy without the need for 2-speed servos and elaborate electronics. By proper impedance, matches up to 64 resolver control transformers can also operate from one resolver transmitter.

TYPICAL CHARACTERISTICS SIZE 25

Type Resolver	Transmitter	Control Transformer
Part Number	Z5161-001	Z5151-003
Excit. Volts (Max.)	115	90
Frequency (cps)	400	400
Primary Imped.	400/80°	8500/80°
Secondary Imped.	260/80°	14000/80°
Transform. Ratio	.7826	1.278
Max. Error fr. E.Z.	20 seconds	20 seconds
Primary	Rotor	Stator

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT

INTEGRATING TACHOMETERS

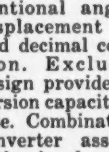
Kearfott integrating tachometers, special types of rate generators, are almost invariably provided integrally coupled to a motor. They feature tachometer generators of high output-to-null ratio and are temperature stabilized or compensated for highest accuracy integration and rate computation. Linearity of these compact, lightweight tachometers ranges as low as .01% and is usually better than ± .1%.

TYPICAL CHARACTERISTICS

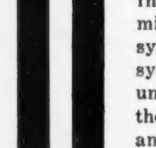
	Size 11 (R860)
Excitation Voltage (400 cps)	115
Volts at 0 rpm (RMS)	.020
Volts at 1000 rpm (RMS)	2.75
Phase shift at 3600 rpm	0°
Linearity at 0-3600 rpm	.07
Operating Temperature Range	−54° +125°

Write for complete data.

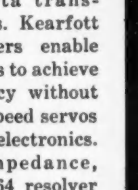
Miniature Floated Gyro



Electrohydraulic Servo Valve



Scanalog 200-Scan Alarm Logging System



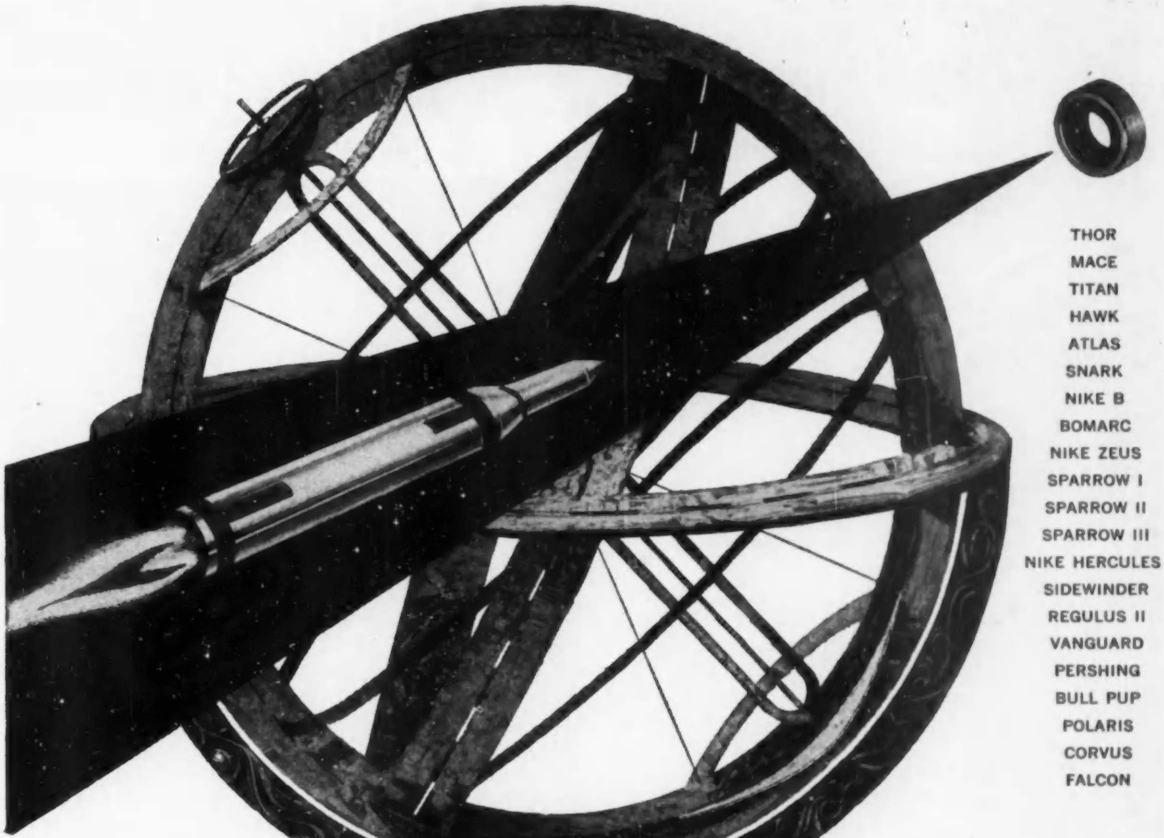
KEARFOTT DIVISION

GENERAL PRECISION INC.

LITTLE FALLS, NEW JERSEY

Midwest Office: 23 W. Calendar Ave., La Grange, Ill.
South Central Office: 6211 Denton Drive, Dallas, Texas
West Coast Office: 253 N. Vinedo Avenue, Pasadena, Calif.

Engineers: Kearfott offers challenging opportunities in advanced component and system development.



ND Adds New Dimensions To High Speed Gyro Rotor Bearings!

At speeds up to 24,000 RPM precision rotor bearings in inertial guidance and navigational systems are highly critical components. Early research and development in design and manufacturing at New Departure is solving the problem and thus winning vital roles for N.D. integral rotor bearings in missile projects. For example, "B" Series bearings with separable inner ring developed by N.D. are helping set performance records in such inertial guidance systems as the AChiever.

New Departure is also supplying high-precision rotor bearings for the inertial guidance system in Polaris. These bearings, through advanced manufacturing techniques, exacting inspections and controlled environmental tests, backed by 50 years of laboratory testing experience, give precision and uniformity far above the most precise industry standards. They promise new performance and *reliability* for the submarine-launched IRBM.

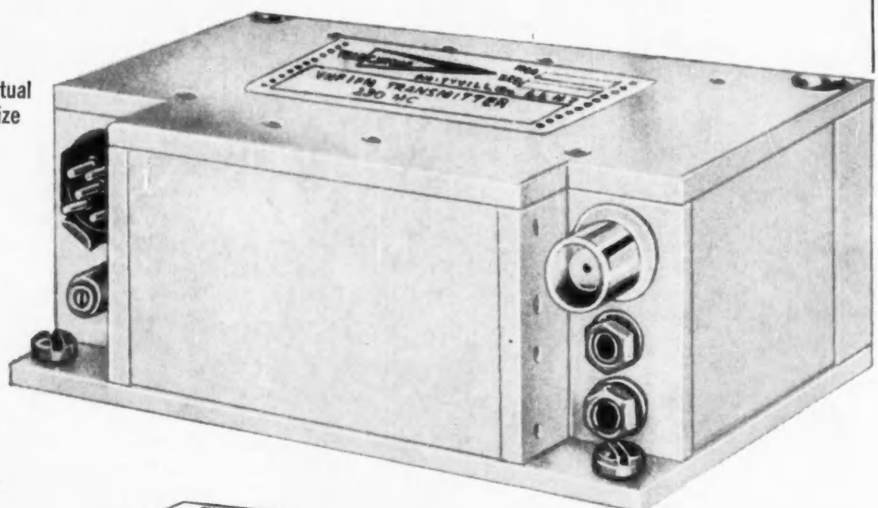
You can look to improved *performance* and *reliability* when you include an N.D. Miniature/Instrument Bearing *Specialist* in early design level discussions. Call or write Department L.S., New Departure Division, General Motors Corporation, Bristol, Connecticut.

NEW DEPARTURE

MINIATURE & INSTRUMENT BALL BEARINGS

proved reliability you can build around

NEW TELECHROME TRANSMITTER*



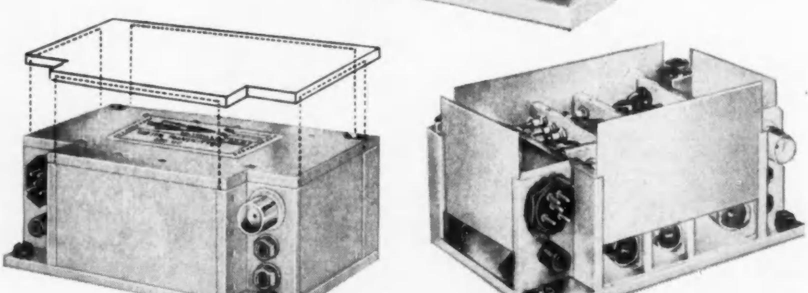
actual size

215-260 mc
FM/FM TELEMETERING TRANSMITTER
Model 1483A1

Features:

- Power output 4 to 5 watts.
- AFC Loop crystal controlled for ± .005% carrier stability.
- Modular construction.
- Silicon Transistors for Low Noise and High Efficiency.
- Modulation Distortion Less than 1%.
- Very low spurious emission
- Plug-in tubes
- −40°C to +100°C
- Size 1⅝" x 2¾" x 4".

Write for Data Sheets



Modular construction
All circuitry mounted on rugged bulkheads. Each may be removed individually for servicing or replacement. Spare modules available. Top of case and side panels removable separately for easy access to all parts.

COLOR TV • INDUSTRIAL INSTRUMENTATION • TELEMETRY

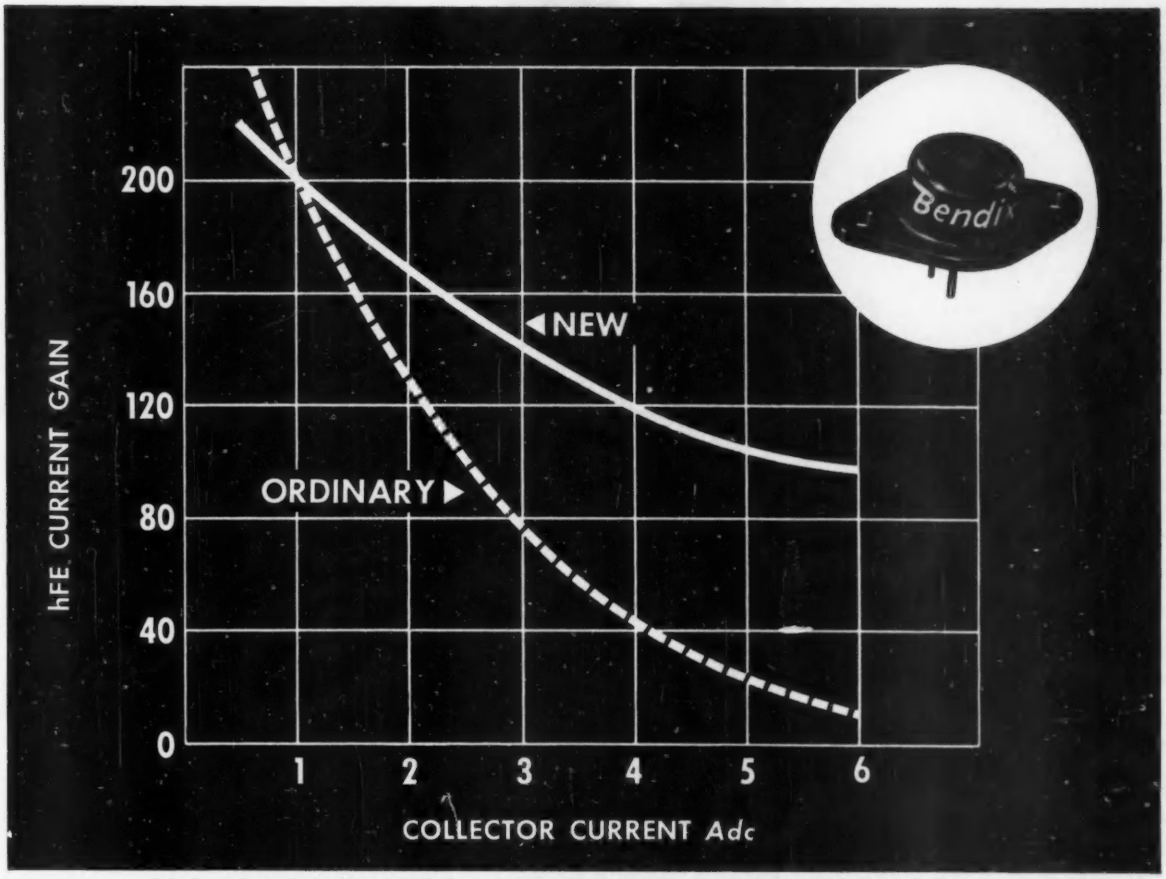
TELECHROME MANUFACTURING CORP.

AT THE FRONTIERS OF ELECTRONICS

TELECHROME MANUFACTURING CORP.
28 RANICK DRIVE AMITYVILLE, N.Y. Lincoln 1-3600
Cable Address: COLORTV TWX: AMITYVILLE NY2314

WESTERN ENGINEERING DIVISION • 13635 Victory Blvd., Van Nuys, Calif., STate 2-7479
MIDWESTERN ENGINEERING DIVISION • 106 W. St. Charles Rd., Lombard, Ill., MAyfair 7-6026
SOUTHWESTERN ENGINEERING DIVISION • 4207 Gaston Ave., Dallas, Tex., TAylor 3-3291

*Even transmits in Russian.



Solid line indicates the low beta fall-off of one of the new Bendix transistors as compared to that of an ordinary transistor.

NEW BENDIX HIGH GAIN INDUSTRIAL POWER TRANSISTORS OFFER FLATTEST BETA CURVE

Now available—a new series of power transistors with the flattest beta curve in the industry, made possible by an exclusive Bendix process. This new series has very high current gains—up to 200 at 3 Adc—and a 10-ampere peak current rating.

Featuring ten-amp performance at a five-amp price, the 2N1136, A, B; 2N1137, A, B; and 2N1138, A, B series provide:

LOW BETA FALL-OFF ——→ LESS DRIVE AND LESS DISTORTION
LOW SATURATION RESISTANCE ——→ GREATER CIRCUIT EFFICIENCY
VOLTAGE BREAKDOWN RATINGS ——→ ELIMINATION OF BURN-OUT
CURRENT GAIN MATCHING ——→ OPTIMUM CIRCUIT PERFORMANCE

Ideally suited for use in static converters and regulators, these power transistors also have numerous applications in relay replacements and drivers for relays, magnetic clutches, solenoids and other loads requiring high current. In addition, their extremely high current gain and excellent hFE linearity make them practical and efficient television vertical output amplifiers and hi-fi amplifiers.

Current Gain hFE at Ic = 3 Adc	Maximum Voltage Rating		
	Vcb 60	Vcb 90	Vcb 100
	Vce 40	Vce 70	Vce 80
50-100	2N1136	2N1136A	2N1136B
75-150	2N1137	2N1137A	2N1137B
100-200	2N1138	2N1138A	2N1138B

For complete information, contact SEMICONDUCTOR PRODUCTS, BENDIX AVIATION CORPORATION, LONG BRANCH, NEW JERSEY, or the nearest sales office.

West Coast Sales Office: 117 E. Providencia Avenue, Burbank, California
Midwest Sales Office: 4104 N. Harlem Avenue, Chicago 34, Illinois
New England Sales Office: 4 Lloyd Road, Tewksbury, Massachusetts
Export Sales Office:
Bendix International Division, 205 E. 42nd Street, New York 17, New York
Canadian Affiliate:
Computing Devices of Canada, Ltd., P. O. Box 508, Ottawa 4, Ontario, Canada

SEMICONDUCTOR PRODUCTS
Red Bank Division
LONG BRANCH, N. J.

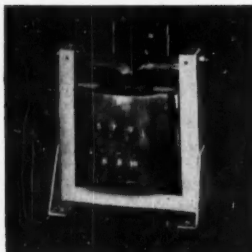
Bendix
AVIATION CORPORATION

CIRCLE 79 ON READER SERVICE CARD

VICKERS®

designers and manufacturers of electrical products and systems for AUTOMATIC CONTROL

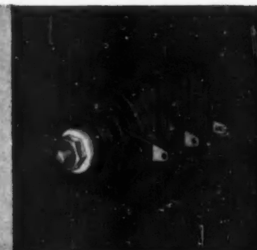
AUTOMATIC CONTROL PRODUCTS



MAGNETIC AMPLIFIERS

"super power", high performance, high power, special purpose (servo, low level, bi-stable, multi-stage and educational) in a complete range of sizes and voltage ratings.

Series 1000 Bulletins.



SELENIUM RECTIFIERS

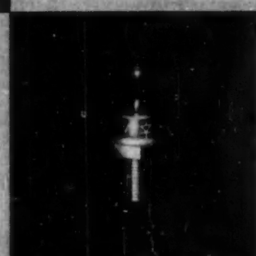
grain-oriented (T. M.) for greater rectifying efficiency, lower cost per watt. Cell ratings from 18 to 36 volts. Microamperes to 1000 amperes.

Series 3100 Bulletins.

SILICON POWER RECTIFIERS

2, 8 and 12 ampere sizes. Excellent operating characteristics, uniform quality, greater economy.

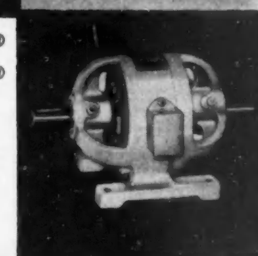
Series 3300 Bulletins.

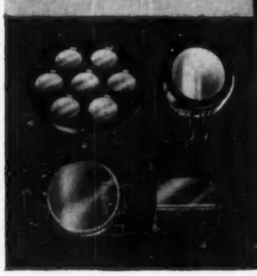


MAGNECLUTCHES® and MAGNEBRAKES®

magnetic particle clutches and brakes. Smooth, flexible operation, fast response, torque independent of speed, long life

Series 6000 Bulletins.

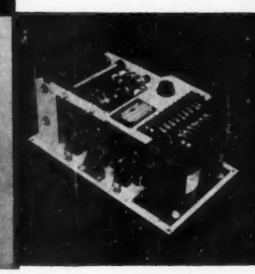




PHOTOELECTRIC CELLS

self-generating, barrier layer type, mounted or unmounted. A wide range of sizes and shapes for standard or special applications.

Series 3200 Bulletins.



REGULATORS and POWER SUPPLIES

for industrial and military applications.

Series 2000 and 9000 Bulletins.

AUTOMATIC CONTROL SYSTEMS

POSITION
SPEED
VOLTAGE
FREQUENCY
CURRENT
PHASE
PRESSURE
TEMPERATURE

Vickers' complete facilities and more than 1,000,000 man-hours of direct experience in design and manufacture of automatic control products and systems are available to assist you with your automatic control problems. Contact the sales offices below, or write direct to us.

EPA-0000-1

VICKERS

VICKERS INCORPORATED

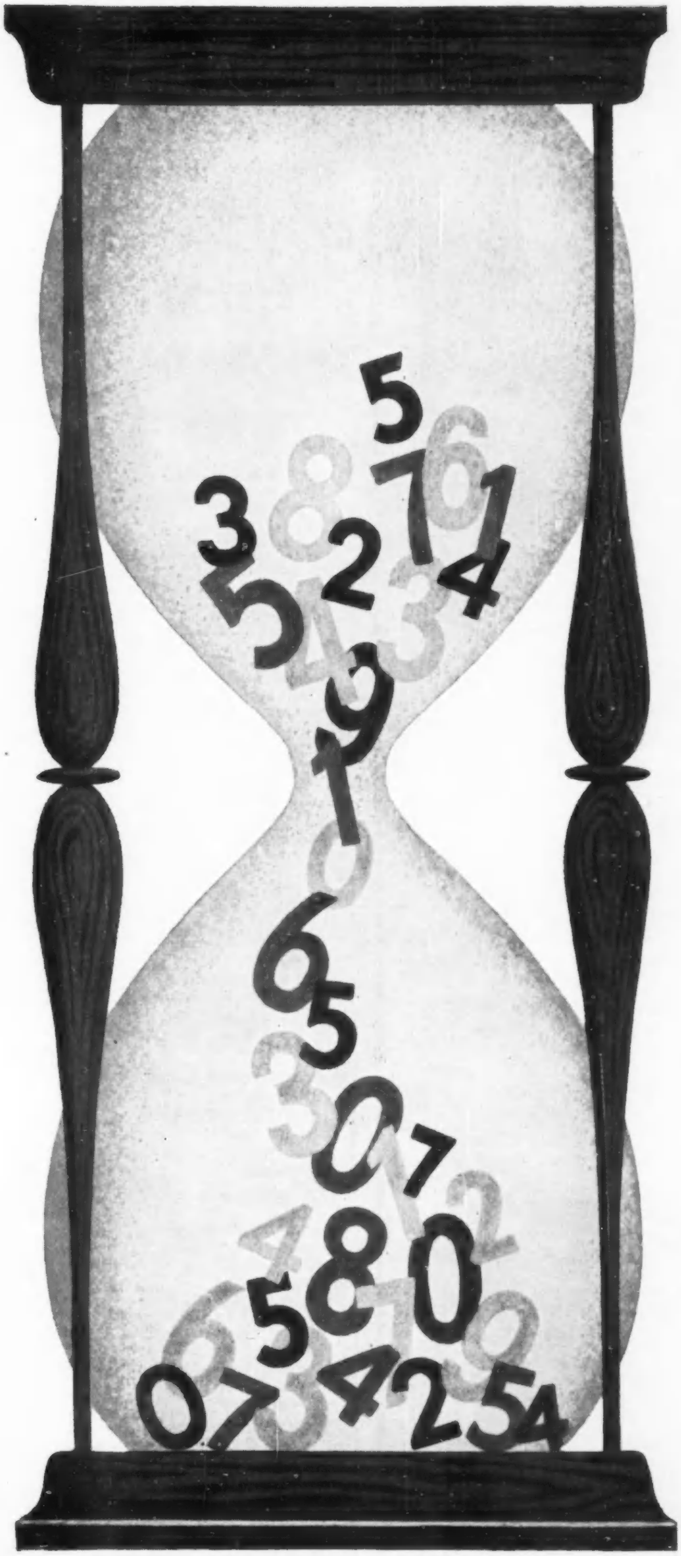
DIVISION OF SPERRY RAND CORPORATION

ELECTRIC PRODUCTS DIVISION

1805 LOCUST STREET • SAINT LOUIS 3, MISSOURI

Sales Engineering Offices

ST. LOUIS—CEntral 1-5830
DETROIT—KEnwood 4-8070
WASHINGTON, D. C.—EXecutive 3-2650
CHICAGO—JUniper 8-2125
NEW YORK—LEnnox 9-1515
CLEVELAND—EDison 3-1355
LOS ANGELES—DAvenport 6-8550
BOSTON (Representative)—CEdar 5-6815



Three generations of ARMA computers:
THE PRESENT GENERATION

6,000
continuous hours of higher mathematics . . . without an error

The thinking apparatus of the guidance system of the **ATLAS ICBM**—ARMA's airborne digital computer—has now completed 6,000 hours of continuous laboratory operation without one catastrophic or transient error.

Fully transistorized, with no moving parts, this remarkable ARMA computer can be relied upon for dependable performance when the **ATLAS** becomes the nation's major deterrent weapon.

Two further generations of ARMA computers will be applicable to even more sophisticated uses. ARMA's advancement of the state of the art has made possible computers—soon forthcoming—that will surpass the present computer's reliability at a small fraction of its weight.

ARMA research and development has made the digital computer truly airborne. ARMA, Garden City, N. Y., a division of American Bosch Arma Corporation . . . the future is our business.

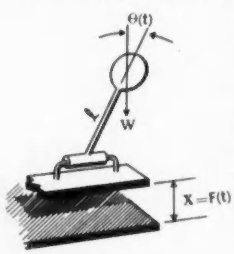
Attention, Engineers: Write to E. C. Lester, Emp. Supv., about career openings in R & D programs.

AMERICAN BOSCH ARMA CORPORATION

DONNER Desktop Computers

The small analog computer you see here accurately predicts system performance with extraordinary speed and simplicity.

To illustrate, consider the problem of stabilizing the inverted pendulum below. Solving this problem requires a rigorous study of the stability of solutions to the Mathieu-Hill equation:

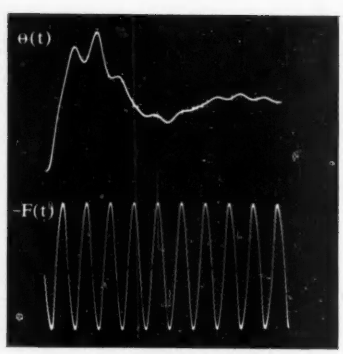


$$\frac{d^2\theta}{dt^2} = \frac{g}{l} - A\,F(t)$$

In just 30 minutes, the computer solved the equations and established definite parameters. An expert mathematician who tackled the same problem at the same time was still working on his second page of calculations! After half a day's work, he had proved only that stability could be achieved—not that it was feasible for this particular pendulum.

The basic computer used in this problem, including two multipliers, costs less than $4,000. It can be readily expanded, initially or as your needs grow. Other Donner computers are available for your particular requirements.

By selecting the proper pivot excitation, $A=F(t)$, the pendulum can be stabilized. The graph shows the time variations in displacement, θ (t) as a function of pivot displacement $F(t)=A \sin \omega t$.



For a closer look at methods of studying non-linear systems with the analog computer, including a clear step-by-step analysis of the inverted pendulum, write for Donner Tech Note #2. We'll also send you a brochure on the Model 3400 computer. Please address Dept. 081.

DONNER SCIENTIFIC COMPANY
CONCORD, CALIFORNIA
Phone MUlberry 2-6161 · Cable "Donner"

Call your Donner rep now for a demonstration

Your nearby Donner engineering representative will be happy to provide you with more information on Donner computers. Let him arrange a demonstration in your plant at no obligation of course. His name and phone number are listed below.

ALBUQUERQUE, New Mexico
Paul Wright (Hyde Electronics)
AM. 8-1111

ATLANTA 5, Georgia
E. G. Holmes & Associates
BL. 5-6660

CHICAGO 31, Illinois
Robert L. Lang & Associates
SP. 4-3610

CLEVELAND, Ohio
Tiby Company
ER. 1-5335

DAYTON, Ohio
Laurence D. Bruno
AX. 3-8703

DETROIT, Michigan
Tiby Company
UN. 4-9298

FORT WORTH, Texas
Mitchell Speairs Company
WA. 6-4444

KANSAS CITY (Shawnee), Kansas
Design & Sales Engineering Company
HE. 2-2528

LOS ANGELES 5, California
Charles W. Fowler Company
DU. 4-7203

NEW YORK CITY (Mt. Vernon), New York
Burlingame Associates
MtV. 4-7530

ORLANDO, Florida
E. G. Holmes & Associates
CH. 1-2128

PHILADELPHIA (Upper Darby) Pennsylvania
Burlingame Associates
SH. 7-9080

SAN FRANCISCO (Menlo Park) California
Ault Associates
DA. 6-1760

SCARBOROUGH, Ontario, Canada
Instronics, Ltd.
AX. 3-7806

SEATTLE 4, Washington
Comptronics
MA. 4-5135

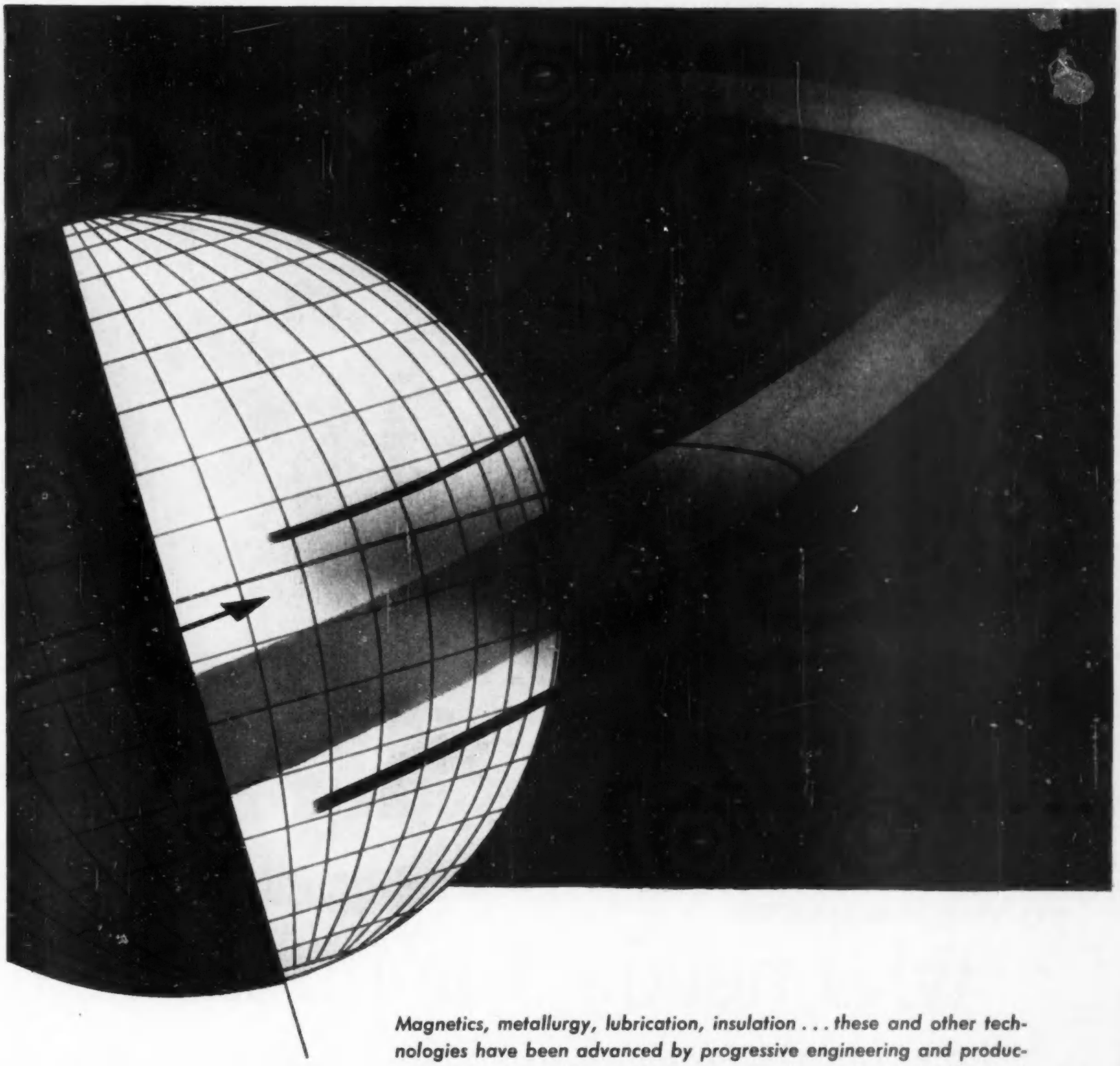
ST. LOUIS 5, Missouri
Design & Sales Engineering Company
PA. 1-6403

STITTSVILLE, Ontario, Canada
Instronics, Ltd.
TA. 8-1253

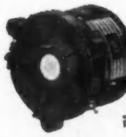
SYRACUSE, New York
Burlingame Associates
GR. 4-7409

WASHINGTON, D.C.
Burlingame Associates
OL. 4-6400

WALTHAM, Massachusetts
Burlingame Associates
TW. 4-1955 17C



Magnetics, metallurgy, lubrication, insulation . . . these and other technologies have been advanced by progressive engineering and production personnel at Eastern Air Devices to make a science of "the act of turning." Since 1942, this scientific approach to the improvement and development of precision rotating devices has resulted in higher output efficiencies, reliable operation in higher ambients and superior performance characteristics under the most severe environmental conditions. In addition to continued product improvement, the application of this science has developed a number of firsts, including variable frequency motors, pure sine wave alternators and thermistor compensation of integrating tachometers. Combine this technical ability with high volume production, unsurpassed quality control, parts standardization for lower cost, and you can see why EAD has been specified by leading systems manufacturers for nearly two decades.



TYPE V1HJ-G8

Miniature Vane Axial Blower

Maximum air delivery in the smallest package

Combining a unique mechanical and aerodynamic design with EAD's standard, reliable 1" diameter motor has resulted in this extremely compact and efficient fan. In addition to the 2 pole characteristics listed below, EAD can supply 4 and 6 pole designs and models for operation from 1600-cycle and variable frequency power sources. Here is another development in the growing family of EAD V-Line vane axial blowers.

TYPICAL CHARACTERISTICS

115 Volt • 400 cycles single or three phase

19,000 RPM nominal

65 CFM at 0" SP

35 CFM at 2.3" SP

Life in excess of 1000 hours at 125°C.

1.5" total length

1.990" housing diameter

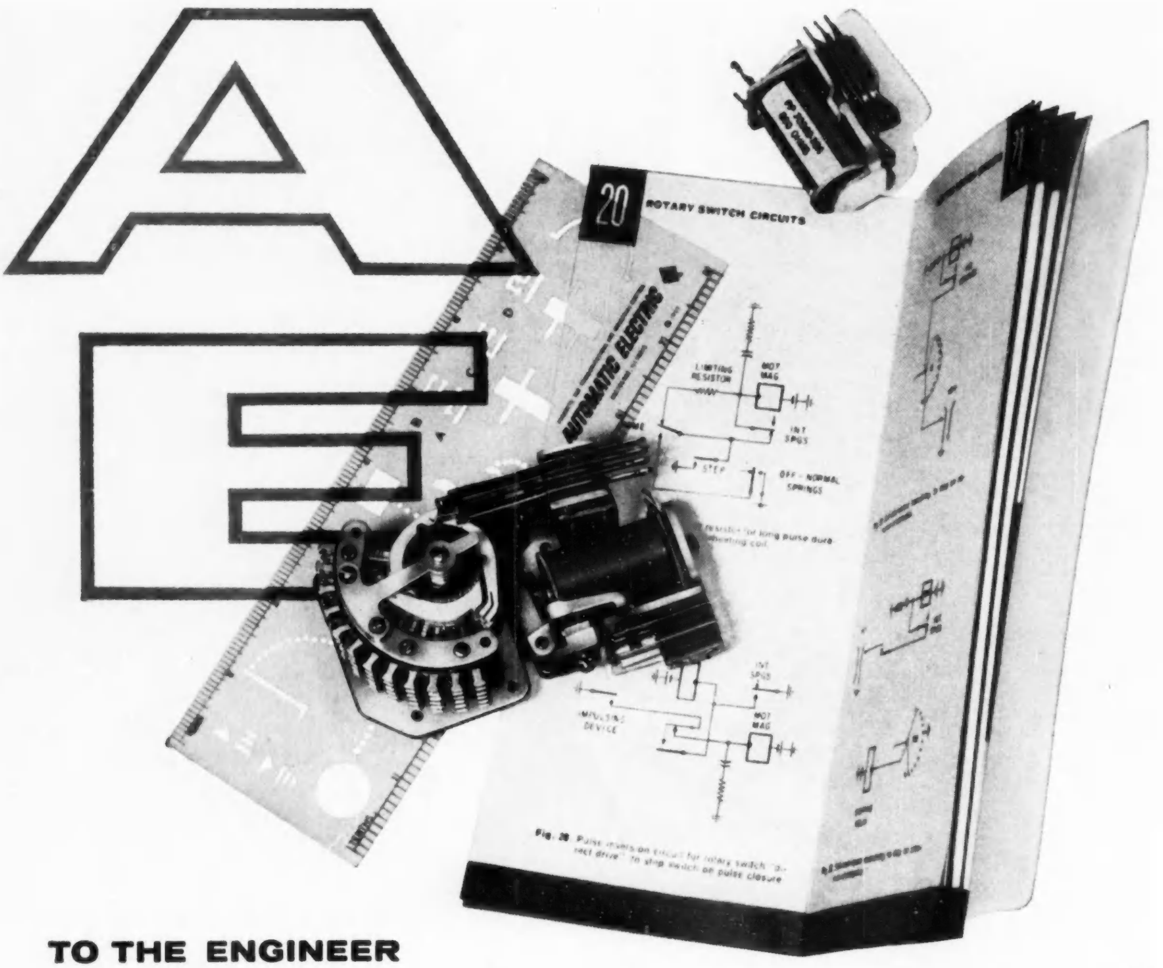
Available with:
1. Leads
2. Terminals on mounting flange
3. Terminals on housing

Write for complete technical data.

EASTERN AIR DEVICES, INC. EAD

Subsidiary of Norbute Corporation • Dover, New Hampshire

INDUCTION MOTORS • SERVO MOTORS • HYSTERESIS MOTORS
INTEGRATING TACHOMETERS AND MOTOR TACHOMETERS • BLOWERS
INERTIALLY DAMPED SERVO MOTORS • TORQUE MOTORS • FANS
DAMPING MOTOR TACHOMETERS • GEAR MOTORS • ALTERNATORS



TO THE ENGINEER

who needs "for instances"

Take such a "for instance" as this: you want to step an indirectly driven rotary switch immediately on pulse closure. The schematic, Fig. 28, above, points out an easy way of doing it with a standard relay.

Or suppose you'd like to stretch a pulse with a relay—or set up a sequential programming circuit with stepping switches. You'll find the most practical methods among the 41 schematics in AE's new 32-page booklet on "Basic Circuits." It comes complete with a handy template for drawing relays and switches on your own circuits. And it's all yours for the asking!

In case you don't find the solution to your switching problem in *Basic Circuits*, our engineers can find a solution for you. In fact, AE engineers can show you switching tricks that will cut corners on costs. Or, if you wish, they'll assume the job of designing and building to *your* specs, anything from a simple control package to an entire system.

To get your copy of *Basic Circuits* and/or the answer to your specific control problem, just write J. E. James, Director, Control Equipment Sales, Automatic Electric, Northlake, Ill. In Canada: Automatic Electric Sales (Canada) Ltd., 185 Bartley Dr., Toronto 16, Ont.

AE CAN DO

AUTOMATIC ELECTRIC GENERAL SYSTEM

Subsidiary of
GENERAL TELEPHONE & ELECTRONICS

RCA

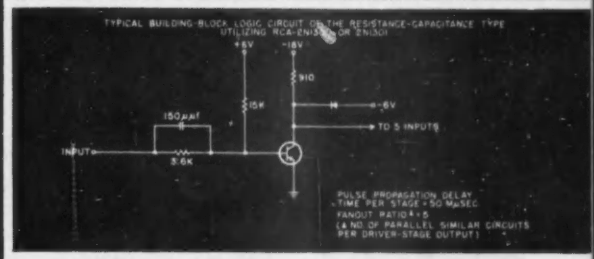
MESA

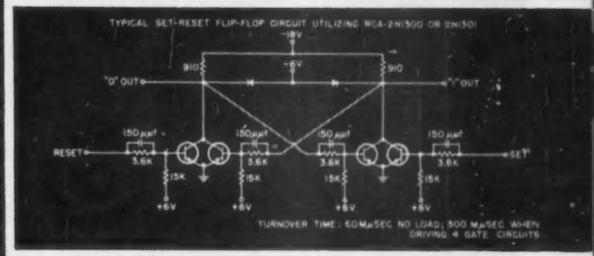
COMPUTER TRANSISTORS

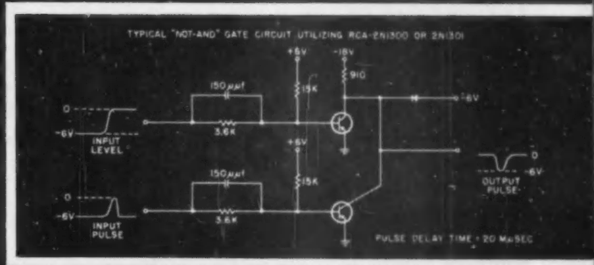
2N1300 · 2N1301

feature

HIGH POWER DISSIPATION
FAST-SWITCHING TIMES
AT LOW COST







AVAILABLE NOW... IN QUANTITY

RCA TYPE	Maximum Ratings—Absolute-Maximum Values							Characteristics: Common-Emitter Circuit, Base Input—Ambient Temperature = 25°C		
	Collector-to-Base Volts	Collector-to-Emitter Volts	Emitter-to-Base Volts	Collector Ma.	Transistor Dissipation Milliwatts			Minimum DC Current Transfer Ratio		Gain-Bandwidth Product▲ Mc
					at 25°C	at 55°C	at 71°C	at collector ma = −10	at collector ma = −40	
2N1300	−13	−12	−1	−100	150	75	35	30	–	40
2N1301	−13	−12	−4	−100	150	75	35	30	40	60
▲For collector ma = −10 and collector-to-emitter volts = −3										

RCA's Germanium P-N-P Mesa Transistors 2N1300 and 2N1301 combine low-cost and quantity availability with these major benefits for designers of switching circuits:

- high power dissipation—150 milliwatts maximum at 25°C, 75 milliwatts maximum at 55°C
- fast switching times—made possible by high frequency response and low total stored charge
- rugged Mesa structure—with an extremely small base width to insure top performance at high frequencies
- high current transfer ratio—permits high fanout ratios (number of paralleled similar circuits per driver-stage output)
- high breakdown-voltage and punch-through voltage ratings—result of the diffusion process
- high current ratings—improves overall system speed
- especially well suited for use at pulse repetition rates up to 10 Mc
- rugged overall design—units have unusual capabilities to withstand severe drop tests and electrical overloads
- electrical uniformity—a result of the diffused-junction process used by RCA in the manufacture of Mesa Transistors

Contact your RCA Field Representative for prices and delivery. For technical data, see your HB-10 Semiconductor Products Handbook, or write RCA Commercial Engineering, Section A-56-NN, Somerville, N. J.

RCA FIELD OFFICES

East: 744 Broad St., Newark, N. J. HUmboldt 5-3900
Northeast: 64 "A" Street, Needham Heights 94, Mass. HIllcrest 4-7200
East Central: 714 New Center Bldg., Detroit 2, Mich. TRinity 5-5600
Central: Suite 1154, Merchandise Mart Plaza, Chicago 54, Ill., WHitehall 4-2900
West: 6355 E. Washington Blvd., Los Angeles 22, Calif., RAymond 3-8361
Southwest: 7905 Empire Freeway, Dallas 7, Texas FLeetwood 2-8663
Gov't: 224 N. Wilkinson Street, Dayton, Ohio BAldwin 6-2366
1625 "K" Street, N.W., Washington, D.C. District 7-1260

ALSO AVAILABLE THROUGH YOUR LOCAL RCA SEMICONDUCTOR DISTRIBUTOR.

Another Way RCA Serves Industry and the Military Through Electronics

RCA RADIO CORPORATION OF AMERICA

SEMICONDUCTOR AND MATERIALS DIVISION · SOMERVILLE, N. J.

FEDERAL SIGN and SIGNAL counts on Tung-Sol transistors to power three-in-one sound device

Federal Sign and Signal Corporation has combined a highly directional electronic siren, a mobile public address system and a car radio amplifier into one compact unit. This unique creation, the Interceptor, arms police patrol cars, fire engines, ambulances and civil defense vehicles with a three-pronged weapon to cope with life-and-death emergency.

The Interceptor counts on Tung-Sol power transistors to deliver the necessary three-purpose power with round-the-clock reliability. Federal, in fact, describes the large complement of Tung-Sol 2N242 and 2N382 germanium transistors as "the heart of the unit".

The 2N242 and 2N382 feature tight parameter control, sure-safe hermetic sealing and efficient thermal design . . . qualities which assure peak performance and long life.

Like every other Tung-Sol component, these semiconductors are the products of carefully disciplined factory processes and rough-and-tough life testing aimed at bringing you the best in componentry.

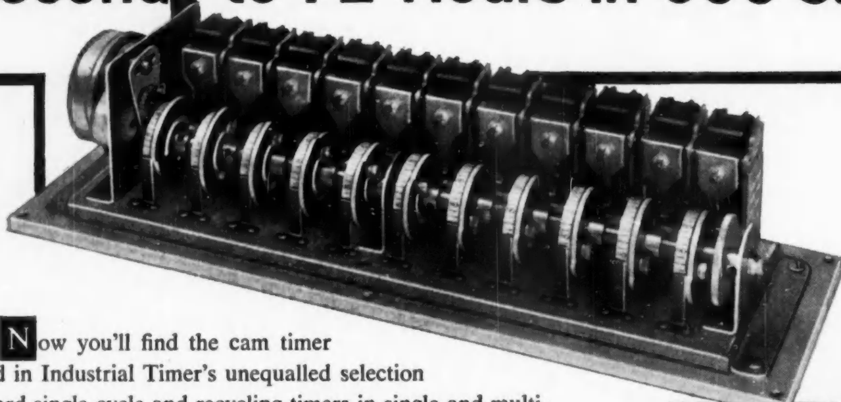
Federal Sign and Signal Corp., the largest manufacturer of sound-producing devices, represents another of the discriminating companies benefiting from Tung-Sol components. Tung-Sol can serve you, too, with premium units for any industrial or military requirements. Get in touch with our applications engineers. They'll be glad to evaluate your circuitry and recommend the components to fit your design. Tung-Sol Electric Inc., Newark 4, N. J. TWX:NK193.

ts TUNG-SOL®

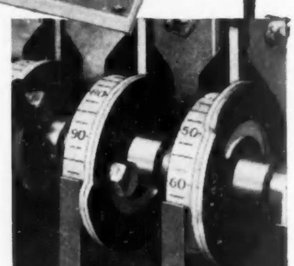
CIRCLE 91 ON READER SERVICE CARD

THE WIDEST RANGE OF CAM TIMERS AND TIME CYCLES

2/3 Seconds to 72 Hours in 600 steps



Now you'll find the cam timer you need in Industrial Timer's unequalled selection of standard single-cycle and recycling timers in single and multi-switch types (up to 50 switches). Every model gives you 50 different overall time cycles, ranging from its lowest cycle up to 9 times that cycle. And standard cam construction lets you adjust ON and OFF periods from 2% to 98% of the total time cycle. Here is unsurpassed flexibility in cam timer selection and function.



If you don't find the timer you want in this unmatched range (a highly unlikely possibility), Industrial Timer's unique Timer Kit will help provide the exact timer you need at low cost. With this kit you can design your own prototype, and since the kit components are standard in our line we can reproduce your prototype—in quantity—*at no extra cost.*

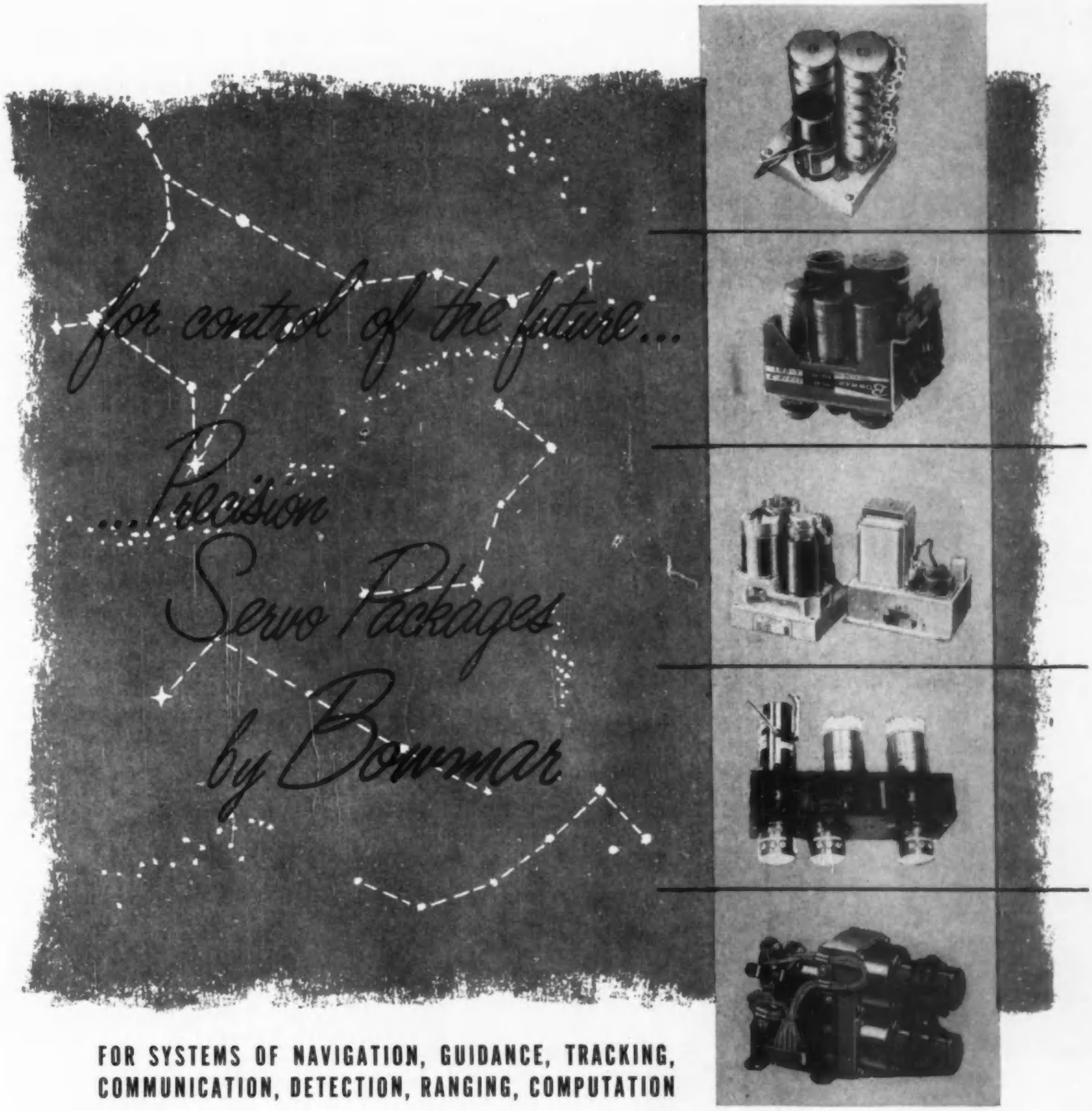
For fast delivery on a standard or special Cam Timer check first with Industrial Timer. For more information ask for *Bulletin 200* Synchronous Motor Driven Cam Timers, *Bulletin 201* Multi-Cam Timer Kit, *Bulletin 202* Multi-Cam Switching Devices.

Industrial Timer's complete line of timers also includes: Time Delay Timers, Interval Timers, Running Time Meters, and Programmers. Bulletins describing these are available on request.

AFFILIATE—LINE ELECTRIC COMPANY

Timers that Control the Pulse Beat of Industry

INDUSTRIAL TIMER CORPORATION
1409 McCARTER HIGHWAY, NEWARK 4, N. J.



FOR SYSTEMS OF NAVIGATION, GUIDANCE, TRACKING, COMMUNICATION, DETECTION, RANGING, COMPUTATION

Original Bowmar concepts in servo design and packaging are playing an important role in space navigation to make "way-side" landmarks out of celestial bodies.

Achievement of these objectives becomes more evident as the nation's leaders in space and flight control systems increasingly utilize Bowmar's collateral engineering skills, production facilities, and servo packaging hardware.

With strong accents on **reliability,** Bowmar has step by step improved the state of the art in precision control, guidance, computation, and communications packages while contributing to extraordinary reductions in system weights and sizes.

Bowmar skills have been demonstrated repeatedly in systems for many of the nation's most important aircraft, missile, and rocket programs. This has been achieved by Bowmar's knowledgeable grouping or packaging of components into complete functional assemblies, ready to perform system **thinking processes.**

These engineering skills and expanding facilities are readily available to help reduce system weight and size while improving reliability.

Bowmar's technical and administrative staffs welcome the opportunity to demonstrate how these skills may be applied to your precision control, guidance or computation systems. Your specific inquiries are invited and will receive prompt replies.

Write for Newest Handbook and Name of Nearest Bowmar Representative

BOWMAR INSTRUMENT CORPORATION

8000 BLUFFTON ROAD • FORT WAYNE, INDIANA

PRECISION ELECTROMECHANICAL CONTROLS AND INSTRUMENTATION, SERVOMECHANISMS, PRECISION MINIATURE GEARHEADS, NAVIGATIONAL COUNTERS, INDICATING DEVICES

The Aircraft Industry Shudders

Cutback of the B-70 program, design of a Mach 3 bomber, threatens to upset aircraft companies—and their control equipment suppliers—more than any event since the cancellation of World War II production contracts. Following close on the heels of the cancellation of the F-108 (Mach 3, long-range interceptor fighter) the B-70 reduction has convinced a lot of suppliers that the days of the giant military aircraft contract are over. At aircraft-oriented Wright-Patterson Air Force Base, long time Air Force employees are even wondering if that famous aircraft development and procurement base might not be shut down. What makes the situation particularly pessimistic for control suppliers is that commercial airlines show little interest in sophisticated devices the control men developed for the military.

The F-108 cancellation (CtE, Dec. '59, p. 50), killed three control systems. Two others—Hughes Aircraft's fire control and Hamilton Standard's environmental control—were saved because they were planned for the B-70 too. Now the subcontractors on these programs face loss of the projects because prime contractor North American Aviation is pulling subcontract work back into its own plant.

Three down

Directly affected by the B-70 reduction were three other control equipment projects that were cancelled: IBM was developing a bombing-navigational system on which $57 million had already been spent; Westinghouse Electric Corp. was working on a defense system, had spent $2.5 million; and Motorola had barely started to develop traffic control equipment (spending was only $300,000).

It now seems doubtful whether the B-70 will ever go into production. The Air Force degraded the project to an R&D status, ordered only two prototype airplanes.

Control makers, who had hoped that commercial aviation, switching to jet liners, might take up some of the slack, now are convinced that such a hope was only a pipe-dream. The airlines have shown little more than scientific curiosity in such items as cruise control, automatic landing systems, all-weather navigation, etc.

Civil market looms . . .

Civil aircraft looms as a good potential market. Sales of small business and utility aircraft have doubled during the period from 1954 to 1958. In 1958, for example, 6,414 such airplanes, valued at $135 million, were sold. With 1959 figures not yet in, industry observers predict the year will set a record for light plane sales, hitting $150 million.

Commercial aircraft (airlines) will drop in numbers but will increase in need for control equipment. The drop in number is caused by the shift to the larger capacity jet liners. As of July 1, 1959, U.S. commercial airlines had this equipment: 1,921 piston-powered planes, 155 turboprop craft, 35 turbojets, and 21 helicopters. By January 1, 1963, the makeup of commercial aviation is expected to change to this 1,050 piston aircraft, 349 turboprops, 305 turbojets, and 30 helicopters.

. . . But no sale

Why aren't these two potential users of control equipment becoming customers? Buyers of light planes usually try to keep their accessory equipment to a minimum—because of cost, inability to maintain it, and lack of knowledge of how to operate it. Some light aircraft carry only a compass, eschew even a simple two-way radio.

For the commercial airlines, the reason is different: inertia. As one veteran aircraft expert put it: "The airlines insist on flying exactly the way they did 30 years ago when they landed on a farm and picked up passengers in front of the barn." And the airlines are letting the Federal Aviation Agency pick up the tab for as much as possible.

Big offerings—no acceptance

Certainly there are a lot of devices already developed that would improve airline service—devices in which the airlines have demonstrated little interest. In 1950, for example, the Air Force demonstrated the feasibility of all-weather, on-time scheduled flying by instrument control. Commercial airlines have ignored this program as if they were proud of their tendency to scramble schedules as soon as the weather turns bad.

Since 1954 the Air Force has studied cruise control, a device to help the pilot fly at maximum fuel efficiency. Air Force pilots found a $1,500 cruise control improved fuel consumption by as much as 25 percent, let jet aircraft fly within 99 percent of maximum design range. Today, only one commercial jet aircraft type has cruise control; Convair is testing it on the 880, which is scheduled to go into service this month.

Anticollision controls are the one sophisticated device that airlines seem interested in (and it took several mid-air collisions to convince stubborn airline executives of this need). But most measurement and control equipment—airborne computers, sophisticated navigation systems, air data systems—are almost totally ignored by commercial operators.

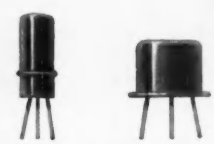
FAA possibilities

The one bright spot in this picture is what may happen at the Federal Aviation Agency. The FAA has started to realize that cow pasture flying is out of date with jet aircraft. The FAA has plans for an extensive R&D program of its own. And over the next few years, the agency seems headed towards a tougher policy of forcing the use of more control equipment, particularly for safety. (One recent example: FAA has required all commercial jet aircraft to carry a radar transponder so the planes can be identified on the ground by air traffic controllers). Even the light aircraft of general aviation will be required to carry a higher level of instrumentation. The big question for makers is when.

PHILCO ANNOUNCES...

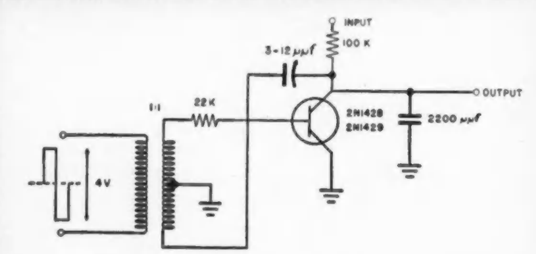
HIGHER FREQUENCY...HIGHER BETA

with Extremely Low I_{CO} in 2 New SILICON TRANSISTORS

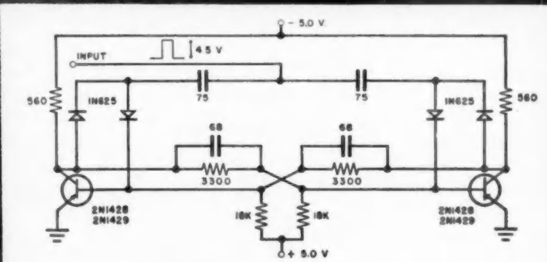


SAT* 2N1428...2N1429

Stable at Temperatures up to 140° C



LOW LEVEL (<1MV) CHOPPER



1 MC BINARY STAGE (−55°C TO +125°C)

These two new Philco PNP Silicon Surface Alloy Transistors are designed for general purpose high frequency amplifying and switching applications. They offer extremely low saturation resistance (approaching that of germanium transistors) . . . high f_T . . . low leakage current . . . good inverse Beta . . . low offset voltage . . . and excellent frequency response. The combination of high Beta and low I_{CO} makes these transistors excellent for use in DC amplifiers, low level choppers and other critical control circuits. They are suitable for:

- . . . high speed switches, operating at speeds up to 5 mc.
- . . . general purpose high frequency amplifiers.
- . . . DC amplifiers.
- . . . high input impedance low frequency amplifiers and choppers.

These two transistors are electrical equivalents, but offer a choice of packages . . . the popular small TO-1 package and the standard TO-5 package. Designers of industrial control and test equipment will find that they deliver excellent performance at high ambient temperatures. **Write Dept. CE-160 for complete information and application data.**

*SAT . . . trademark PHILCO Corporation for Surface Alloy Transistor

Absolute Maximum Ratings

Storage Temperature	**−65 to +140° C**
Junction Temperature	**+140° C**
Collector to Base Voltage, V_{CB}	**−6 volts**
Collector to Emitter Voltage, V_{CEO}	**−6 volts**
Collector Current, I_C	**−50 ma**
Total Device Dissipation at 25° C (Note 2)	**100 mw**

Immediately Available in Production Quantities...and from 1 to 99 from your local Philco Industrial Semiconductor Distributor.

PHILCO®

LANSDALE DIVISION • LANSDALE, PENNSYLVANIA

TRANSISTOR CENTER U.S.A.®

CIRCLE 98 ON READER SERVICE CARD

Control
ENGINEERING

JANUARY 1960

Control Still Expanding

Through their own experiences in the last six years, engineers have seen the control field form. The formative process integrated elements in a way that has confounded manufacturers, educators, marketing people, and some engineers who had neatly tucked the elements into pigeonholes. Yet with little strain the new field has accommodated:

- design and application
- mathematical abstraction, hardware, and clever improvisation
- electronic, pneumatic, hydraulic, optical, and electromechanical techniques
- aero-space and industrial applications
- process instrumentation and industrial control

While the field gathered its elements, it spawned developments that caught up with the ideas of even the most visionary forecasters. For instance, during the six formative years numerical programming of metalworking and metalforming machinery went all the way from an idea to commercial payoff. Toward the end of the period computing-control of manufacturing processes and missile flight began to emerge from a maze of difficult identification and programming problems to find an expanding range of profitable applications.

Our forecast of control in the sixties (pages 101 to 107) reveals our conviction that the field has by no means jelled; that it will add a dimension or two, grow from a field into "a universe of automatic systems". These systems will encompass more and more of the design and management phases of business and industry. They will also include areas of intelligence, such as automatic translation, abstracting, learning processes, and teaching. Because they will depend upon equipment and technology with which the well-informed control engineer has become familiar, it follows that they will fall within his province and that we will cover their design and application during the new decade.

But not enough of the varied types of engineers drawn into instrumentation and control work have taken the opportunity to fully inform themselves. "Squeaky wheels" have had their attention; information control and new mathematical tools for systems synthesis have not. These engineers and new recruits to the field will face an increasing need to know the fundamentals of controlling information as well as the practices of controlling machines and processes. To fill their needs we will devote increasing attention to applied information theory and applied switching. To match the nature of the expanding applications we will adapt statistical techniques, game theory, and linear programming to the needs of the automatic systems engineer.

W. E. Vannah

This new precision DC VTVM is also a wide range, precision ohmmeter and ammeter!

1% accuracy 100 µv to 1,000 volts!

Also 2% accuracy, 1 µa to 1 amp full scale.

Measures 0.02 ohms to 5,000 megohms.

No zero adjustment. 1 minute warm-up.

Floating chassis. $1,000 worth of convenience for $350!

Haven't you wished for one compact, simple instrument that would make *precision* dc voltage, dc current and resistance measurements over a wide range?

The new hp 412A is it! In its VTVM circuit, the 412A uses an exclusive hp photo-chopper instead of old-style mechanical vibrators—no drift, no 60 cps pickup. Input is floating, with resistance increasing from 10 megohms on the 1 mv range to 200 megohms on ranges above 100 mv. Current and voltage ranges have a 10 db sequence for maximum readability and overlap. The ohmmeter is a modified Kelvin bridge eliminating lead resistance error; you measure resistance accurately on hook-up wire sections as short as 6″.

Model 412A also includes a 1 v or 1 ma recorder output, and 3 separate probes. Call your hp rep today for a demonstration on your bench. Price, $350.

HEWLETT-PACKARD COMPANY
1001H PAGE MILL ROAD • PALO ALTO, CALIFORNIA, U.S.A.
CABLE "HEWPACK" • DAVENPORT 5-4451
FIELD REPRESENTATIVES IN ALL PRINCIPAL AREAS

hp 400L LOGARITHMIC VOLTMETER—$325
New hp voltmeter covers 10 cps to 4 MC; accuracy high as ±2% of reading or 1% of full scale. Voltage range 0.3 mv to 300 v, 12 ranges, 1-3-10 sequence. Max. full scale sensitivity 1 mv. Large 5″ true log voltage scale, linear 12 db scale, generous overlap. High stability, high input impedance. Also useful as amplifier for small signals, or to monitor waveforms.

hp 400H PRECISION VOLTMETER—$325
Extreme accuracy as high as ±1% to 500 KC, ±2% to 1 MC, ±5% full range. Frequency coverage 10 cps to 4 MC. Large 5″ meter with precision mirror scale. Voltage range 0.1 mv to 300 v; max. full scale sensitivity 1 mv. High 10 megohm input impedance minimizes circuit disturbances. Amplifier with 56 db feedback insures lasting stability. Reads direct in db or volts.

hp 400D WIDE RANGE VOLTMETER—$225
Highest quality, extremely versatile. Covers 10 cps to 4 MC. Highly sensitive, accurate to within ±2% to 1 MC. Measures 0.1 mv to 300 v; max. full scale sensitivity 1 mv. Reads direct in dbm. High 10 megohm input impedance virtually eliminates circuit loading. 56 db amplifier feedback insures high stability and freedom from change due to external conditions.

Data subject to change without notice. Prices f.o.b. factory

5028

hp complete precision voltage measuring equipment

Control Enters a New Decade

WILLIAM E. VANNAH
Control Engineering

Economists have peered into the coming decade and foreseen "The Golden Sixties". Labor unions have laid out a schedule of objectives that may lead to a four-day work week sometime in the sixties. Business editors predict that "plants with unblievable automaticity" will be built to produce the economic bonanza and to make possible a shorter work week. Both will hinge on automatic systems of a more and more sophisticated character. Here is our forecast of their scope, form, and direction.

Interview after interview with planners and thinkers in the field has confirmed the belief of the editors that the pace of control will accelerate and that its province will expand into a broad universe of automatic systems—led by automatic information systems and closely followed by emphasis on larger capacities and faster speeds of power converters and actuators.

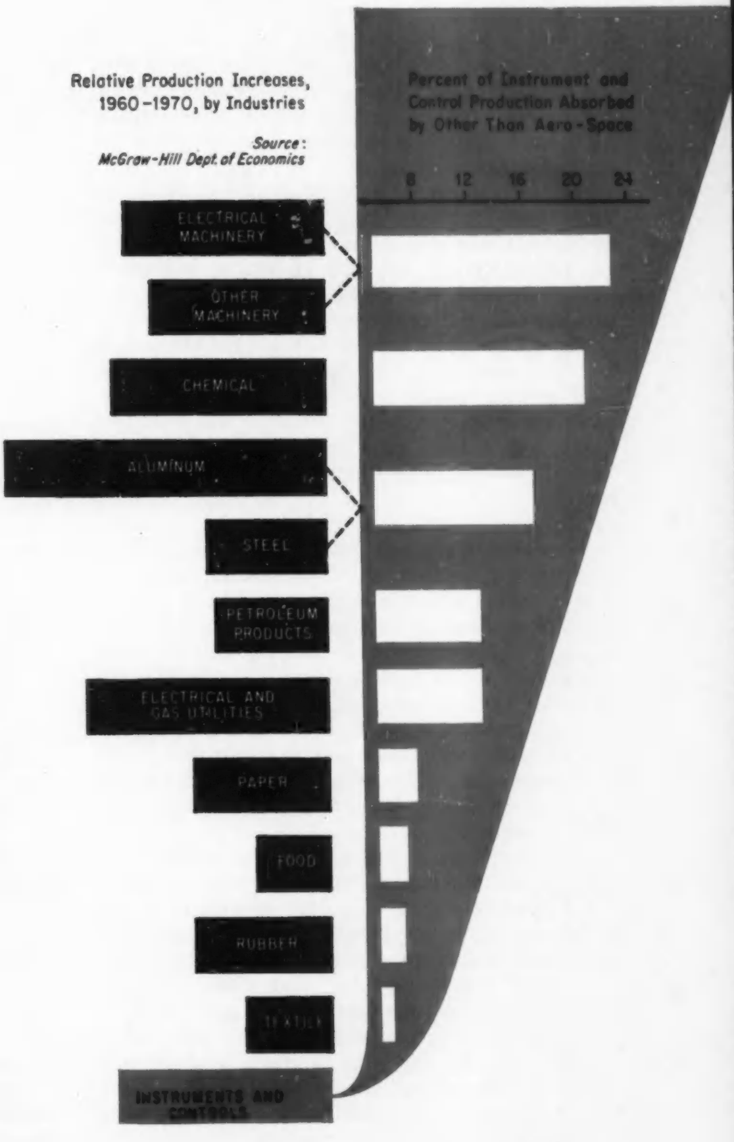


FIG. 1. Production of the instrument and control industry will increase more than that of any industry other than aluminum and utilities. Aerospace will absorb up to sixty percent of the production. Machinery and chemical industries will take nearly half of the remainder.

Expenditures will treble if labor transitions are made

Three key influences will determine the basic nature and scope of the control engineer's work: growth in the national product, increase in the use of control products to effect the production growth, and the development of new control techniques. The left of Figure 1 reveals the production growth expected in major industries during the new decade. All are industries in which control engineers are becoming more active. The colored bar represents the probable increase in production of products that the control engineer will apply. The right of Figure 1 presents an estimate of how manufacturing industries may absorb the production. Together, the two sides of Figure 1 offer substantial evidence that the abilities of the control engineer at making operations more automatic will be in even greater industrial demand than during the past five years.

The nature and source of demand for his services will vary throughout the decade. During 1960 the steel, chemical, aluminum, machinery, automotive, paper and pulp, and rubber industries will work him hard. All of them plan to increase their capital expenditures by more than 20 percent. Full work schedules will be true in the aerospace industry during the first half of 1960, but toward the year's end one control engineer in five may find his projects running out because of Administration plans for concentrating major aerospace programs. Heavy industry, particularly steel and aluminum, will stress getting the job done rapidly and yet with advanced equipment, for it is determined to carry through extensive modernization. During 1961 the manufacturing industries will begin to taper their capital expenditures. Economic justification will become more important as the year progresses and will become crucial during the recession expected toward the end of the year or early in 1962.

Economists say that our current economic cycle has slid over the capital investment boom phase of the four-phase cycle: consumer spending, capital investment boom, plateau, and recession. The capital investment and plateau phases are merging. However, they believe that the next cycle will pass through all of the phases and will run a course of six or seven years. If this comes to pass, the control engineer should encounter a heavy and steadily increasing demand all through the middle of the decade. Ambitious approaches and highly sophisticated systems tried out technologically and economically early in the sixties will be welcomed. If all of the economic, social, and technological pieces fall together as they are expected to, the control field will expand into a universe of automatic systems. During the expanding years the man we now call a control engineer will become an automatic systems man, truly a "doctor of performance".

Over the rosy picture hangs a persistent cloud—the growing problem of transforming workers who are displaced by technologial advances. The industries that expect the greatest increases in production and in the use of more-inclusive automatic systems are the same industries that have already entered on a round of negotiations over work rules. On one side is the necessity of adopting technological advances to remain competitive nationally and internationally. On the other side is a very real obligation to displaced workers. Obligation and necessity must be joined. Otherwise labor trouble or fear of labor trouble will slow to a walk the control application pace that we have forecast.

Momentum will extend applications, primarily in piecemeal fashion

Completely automatic production control of an electric apparatus fabricating plant will go on-line this year. A dozen major chemical processing units will be computer controlled. Such technological milestones will excite the field. They will snowplow the way to economically important systems of even grander scale at mid-decade.

Until then, however, most of the progress will be piecemeal. One control engineer calls it "creeping automation". An electrical manufacturer succinctly refers to it as "forming islands of automation". It is the process of steadily closing one information loop or control loop after another. Through it the momentum of instrument and control means introduced in the late fifties is carrying the field into the new decade. Because they are proven means and because there is available an adequate technology for handling peculiar control problems with them, their applications will spread to operations not previously regarded as prime prospects. Static switching is a striking example. Magnetic amplifier static switching is being joined by transistorized static switching, hybrids of the two, and hybrids with improved electromechanical relays and contactors. From this switching family compatible hybrids will be selected for newfound applications: conveyor controls, annunciator systems, programmers, automatic processing lines, automatic warehousing, and eventually machine tool control. From the same family other hybrids will go into a growing variety of launching, checkout, and inspection systems for missiles and space vehicles.

Control of electrical power generation and distribution demonstrates the time scale and scope of the piecemeal approach. Informed sources state that computer control systems will:

- execute programming of automatic startup, shutdown, and constant operation by 1962
- calculate plant performance and accordingly control variables to produce more nearly optimum performance by 1962-3
- back up individual control loops by 1962

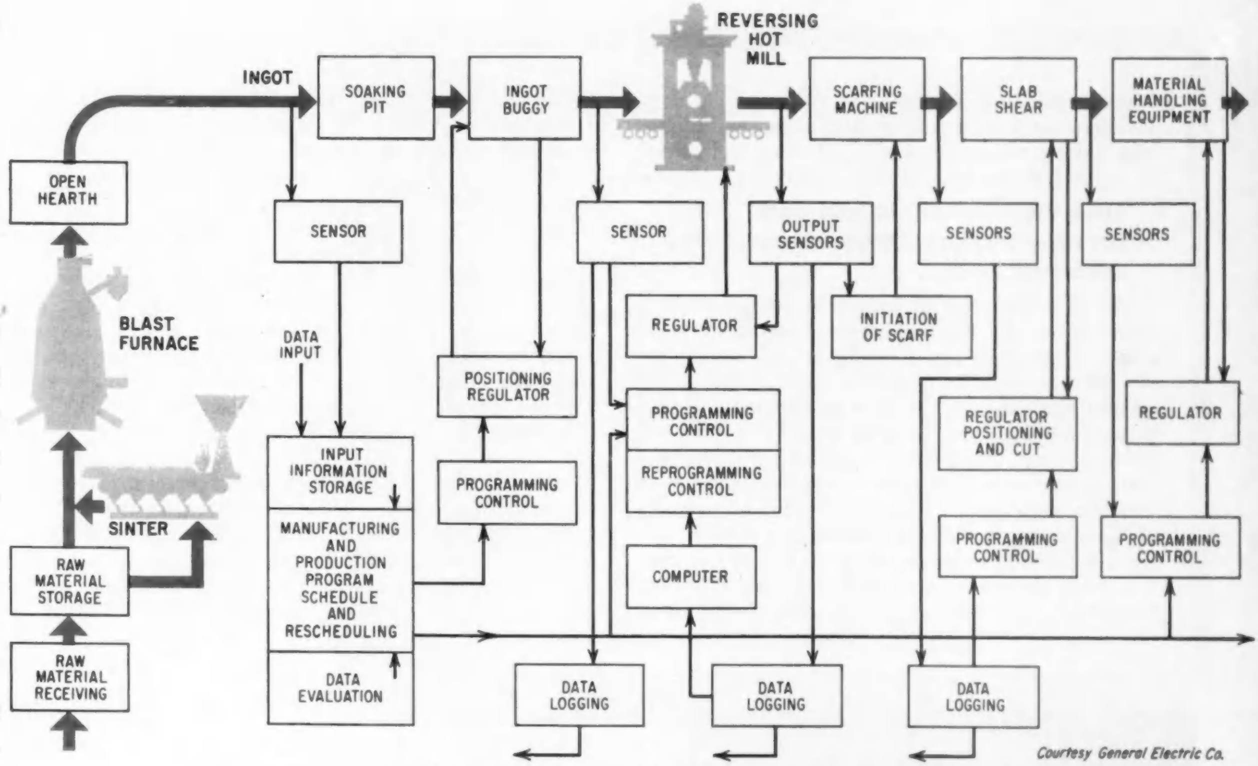


FIG. 2. The closing of one information or control loop after another to interconnect automatic production units will bring about the fully automatic steel mill. Graphic symbols denote production islands which are largely automatic now. Users will perfect the information systems and formulate control functions; makers will engineer the hardware systems.

• supplement individual control loops with noninteracting variables control before 1965.

The first fully automatic generating system will be in operation by 1970, but probably not earlier. It will fulfill three functions:

• continually compute incremental operating efficiencies to trim the incremental cost function-generators of each unit (present function generators use month old efficiency data)
• predict loads by one-half hour in advance so that auxiliaries or units can be automatically warmed up in time to handle new loads
• compute maintenance schedules, program outages, plan system load growth, and account power bought and sold overinterchanges. A joint Philadelphia Electric-Minneapolis-Honeywell development program is already attacking the last item.

Advances in the basic steel industry point up additional factors of the piecemeal approach throughout industry: the tremendous number of compatible interconnections to be made, a need to "know the process" much more completely, and a need for refined instruments. Figure 2 shows some of the pieces or islands to be instrumented and linked. All three factors lead engineers at American Steel & Wire and at Jones & Laughlin Research to feel that information systems will get predominant emphasis for the next three years. Information systems encompass measurement, data transmission, data storage, computation, programming, and presentation. Devices for carrying out most of these functions are available or may be adapted. For instance, blast furnace charge analyses will be made by X-ray emission and nuclear magnetic resonance and fed directly to computers for determining process interrelationships. By this method steel industry control engineers and control system manufacturers will close loops one at a time until, by 1964, they will have completely integrated blast furnace control in hand. Open hearth furnaces will get the same treatment but progress will be slower. Complete computer control of new processes such as oxygen enrichment may come about sooner, for process and computing-control system will be tailored from the beginning.

Automatic inspection of products which have not been made automatically offers one more example of how initial emphasis on information systems in new problems will lead to fully automatic control. It has become economically practical to automatically inspect fabricated products that could not be automatically made. The statistical quality control information now produced by automatic inspection systems will be used to automatically regulate fabricated product manufacture. Special computers using hybrid analog and digital techniques will reduce real time quality data and feed it to stored program digital

systems that will furnish the links for currently available machine regulators and actuators. In this way the use of regulators and actuators will extend to heretofore uncontrollable fabricating operations.

New requirements will call for new means, larger capacities, faster speeds

By 1970 designers of industrial equipment will more than double their purchases of adjustable speed electric motor drives. Dc drives will dominate. Adoption of solid-state devices such as the silicon controlled rectifier will bring in smaller, more reliable power packs for them. In ac drives, development will continue on improved insulation, notably the epoxies, and on wound rotor motors controlled with magnetic amplifiers. F. C. Willams of the University of Manchester, England, has invented a variable pole pitch induction motor in which continuous four-to-one speed control is an integral part. His group has built 50-cps and 400-cps motors with efficiencies as high as 67 percent. Under R. M. Saunders at the University of California (Berkeley), experimental construction of similar motors is nearing completion for derivation of design and application principles. See "Strange New Ball Motor", page 131 of this issue, for another development in adjustable speed ac motors. The power required to vary the speed of these motors, their power handling capability, and their speed of response will improve sufficiently by mid-decade for adoption by industry.

Controls with higher intelligence will require a multitude of memory and decision elements. Single modules for all logical connective operations—AND, OR, NOT, NOR, delay, conversion, and memory—are now on the market. Complete modulator and flip-flop circuits made of single semiconductor crystals have evolved from defense miniaturization programs. Packages containing functional combinations of logical operations will be introduced this spring and will hit their full application stride by mid-1962. Matchbox-size epoxy potted cans will contain one or

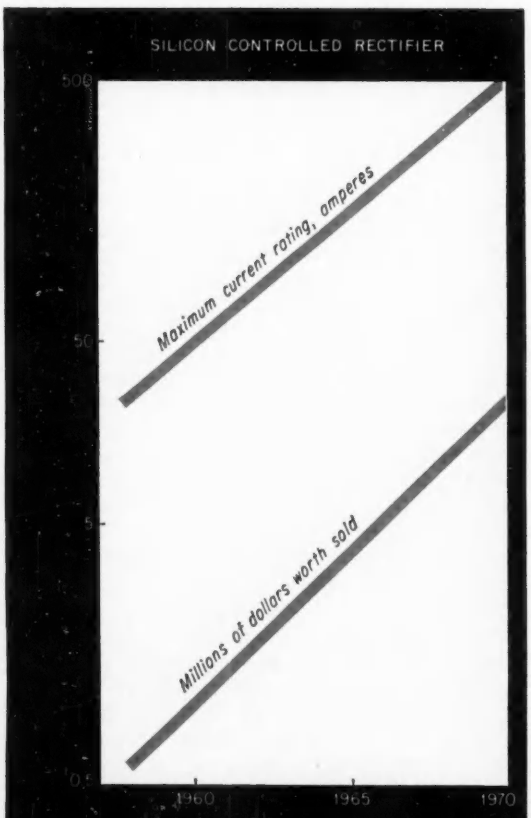
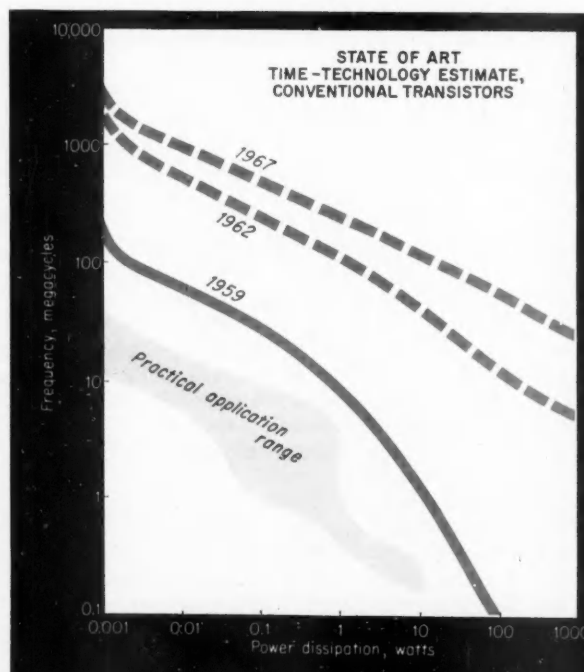


FIG. 3. Mass-produced silicon controlled rectifiers will increase their current ratings and dollar volume sold by an order of magnitude in ten years; they will compete with all other types of rectifiers, from glass thyratrons to metal tank ignitrons.

FIG. 4. Manufacturers will refine transistor designs and production techniques to get consistent quality at triple the production rate. Exploitation of fusion techniques will advance power and frequency ranges to theoretical limits.



Courtesy C.H. Zierdt, Jr., GE Semiconductor Products Dept.

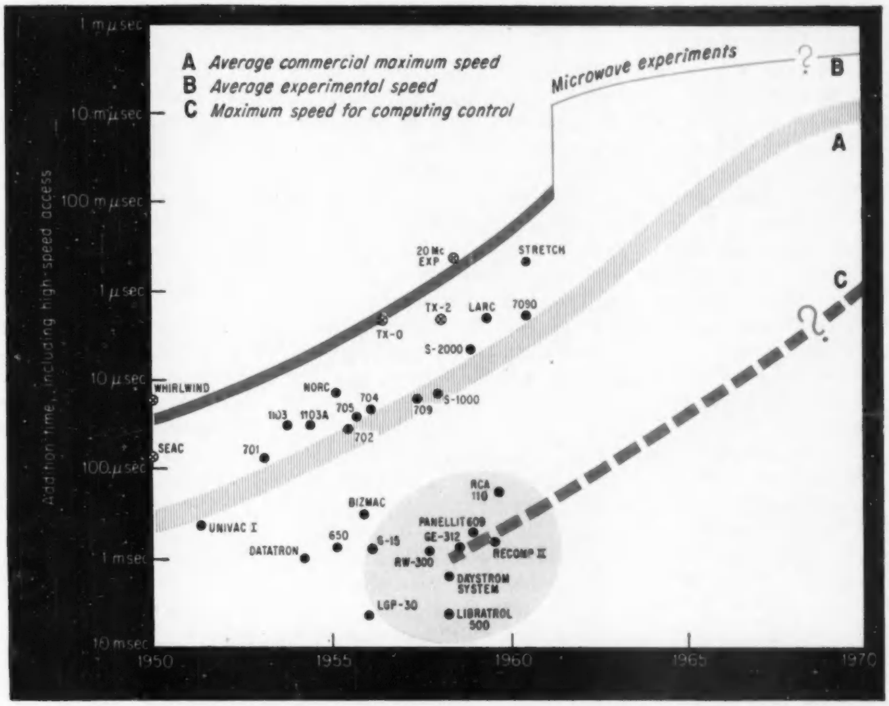


FIG. 5. Maximum computing speed (when introduced) of commercial computers introduced since 1950 and expected increase in maximum computing speed through 1970, curve A. Based on time to add two 10-digit numbers.

Maximum computing speed of experimental computers, curve B. Will solid-state techniques cause an upward bend and jump? Curves A and B flatten and approach one another above ten millimicrosec computing speed because of expected pulse timing limits of components physically only wavelengths apart.

Will maximum computing speeds of computers for industrial control follow curve C?

another of these complete functions:

• counting
• entire shift register
• code conversion
• microminiaturized magnetic digital-to-analog conversion that will include all necessary decision logic
• comparator, in which a bidirectional counter takes the algebraic sum of command and measurement information, and a digital-to-analog converter produces the result in analog language for control action.

Such functional logic packages introduced this spring will be a boon to the man who tackles computing-control by biting off unit operation by unit operation. By 1961 he will be right in the middle of a major controversy over whether control computers should be general purpose or special purpose. He will contend that his unit-by unit approach is tailored to his pocketbook and to his knowledge of the things to be controlled. The approach is an extension of present control practice. He will also explain that plant engineers can follow the relationships between his programming and the process variables because the configuration in which he arranges the functional logic packages, or patchboards of a special purpose analog computer, is his basic programming.

Computing-control problems growing out of the unit-by-unit approach will require general purpose digital computers of all ranges. The shaded area out of which curve C in Figure 5 rises represents the present speed range of digital computers for industrial use. Average computing speed for industrial problems is several orders of magnitude below the maximum speeds of commercial computers shown by curve A. But once automatic inventory and automatic scheduling systems are tied in closed loops to computer controlled production processes, the immensity of the necessary high speed memories will require much greater computing speeds. Does curve C predict the consequence—that the scope of applications tackled by 1970 will require the speed of the fastest computer built to date?

Needs of mechanical processors of metals, plastics, and glass for continuous measurements of product quality and for in-process physical characteristics will spur development of a battery of higher resolution instruments. Magnetic read-and-erase measurements of running length and radiant energy measurements of thickness are available now. An optical means of measuring surface quality, complete with complex logic circuitry for evaluating quality, will be introduced by a steel maker this year. But yet to come are completely satisfactory methods of continuously measuring sheet width, tube eccentricity, hardness, modulus of elasticity, inclusions, faults, and curvatures of structural cross-sections. Eddy current techniques should meet some of these needs. Higher resolution process instruments for measuring weight, liquid level, and flow rate will come on the market by 1965 under the impact of processes with higher resolution and the requirements of continuous inventory and yield control systems.

Interest in dynamic display—the display of information which changes rapidly—has mushroomed with the introduction of complex electronic systems

for air traffic control, for complex simulation, for tactical defense systems, and for large production control systems. Three main developments are underway: new cathode ray tubes, optical techniques, and miscellaneous devices. In the next ten years flat cathode ray tubes with pictures three times brighter and 20 times sharper than conventional cathode ray tubes will come into widespread use. Three-color display and three-dimensional display models will be available. In optical techniques the major emphases will be on use of color and on improvement in the resolution and brightnesss of the TV picture. Isometric display is under study. Electroluminescent materials will find wide application in miscellaneous display devices.

Probably the most dramatic improvements in automatic systems will come about through efforts to get man in space. A manned station and commuting rocket ferries will be in service by 1965 if a joint proposal by Hughes Aircraft and Lockheed is carried through. For the prefabricated pieces of the station to hit the carefully selected orbits necessary for assembly of the station would require guidance systems better by at least an order of magnitude than those available today. The accuracy of gyros with mechanical bearings will be insufficient. Minneapolis-Honeywell has announced a beryllium gyro rotor suspended electrostatically in a hard vacuum. Use of nuclear spin momentum and vibrating crystal lattices are other possibilities. In a shorter range approach to improved accuracy, Ford Instrument Co. is building a platformless inertial guidance system. A digital computer will continually calculate and compensate for accelerations measured by inertial accelerometers. Strides in miniaturizing digital computers will make possible this approach.

The sensitivity of electronic devices to extreme temperature ranges and highly radioactive fields will require development of miniature pneumatic and mechanical components for computation and actuation in aerospace vehicles. Pneumatic, mechanical, and electronic systems will trend toward all-digital so that loop language will be compatible.

Control objectives will spread from production to management and design

Control engineers will continue to bring productive elements, that is machines, vehicles, and processes, more completely under control. But their objective will spread beyond the control of productive elements to automatic control of complete businesses. Here the productive element will comprise one subsystem in a complex multiloop feedback control system. The input to the subsystem will be commands from management, engineering, market research, and product design specifying how much of what to make. Its output: product, plus information feedback. Once outside the producing subsystem the problem will be primarily one of controlling information. Information on markets, customer demands, transportation options, competition, raw material sources, and production status will be rapidly digested by data processing machinery to yield management guidance and dynamic commands that tell what to make, how to distribute it, where to store it.

The advent of computer controlled processes and machines means that production commands can be generated more directly in the creative groups. Design machines that incorporate physical design capabilities with routines for converting information into production command language will draw production and engineering more closely together.

The dynamic characteristics of entire businesses will become important. The flexibility and more rapid chanageability sought in production today will be the goals of whole businesses. Physically it will mean the interconnection of business data handling equipment with product design equipment and automatic production control loops.

Examples demonstrate that some progress has been made toward the new goal. A parts supplier uses a digital computer to schedule steel sheet substitution, to keep track of in-process inventory, and to forecast machine loads. An automobile manufacturer uses a computer to match assembly and parts production with customer options. A petroleum products producer regulates the production of widespread refineries in accordance with weather, inventories, competitive action, international situations, types of crude on hand, and maintenance schedules. Figure 6 shows an example that starts with computer controlled production and looks toward the complete computer integration of an entire telephone manufacturing and supply system.

Prototype systems for automatic design already convert design shapes to mathematical formulas, optically present shapes, prepare tables, and convert formulas and tables to numerical programs through Automatically Programmed Tool (APT) languages. Soon a manufacturer of drafting machines will introduce a machine that will prepare layout drawings at the same time that the metal-working program computer prepares numerical programs. The APT programs will extend to the calculation of stresses, deflections, structural dynamics, and complex structural members modelled after bone structures. Tapes will also program materials handling machines located between metalworking machines. Beyond all this is a mushrooming variety of automatic systems that will translate documents, abstract and retrieve technical information, and perform differential medical diagnosis. All of these operations are based on logic; where the logic is clear and the vocabularies are well-defined, progress will be rapid. But where interpretation and perception are necessary and where the vocabulary is the product of techniques gathered from many scientific disciplines, progress will be slow. Ironically, this is true of cross-discipline functions like control and energy conversion.

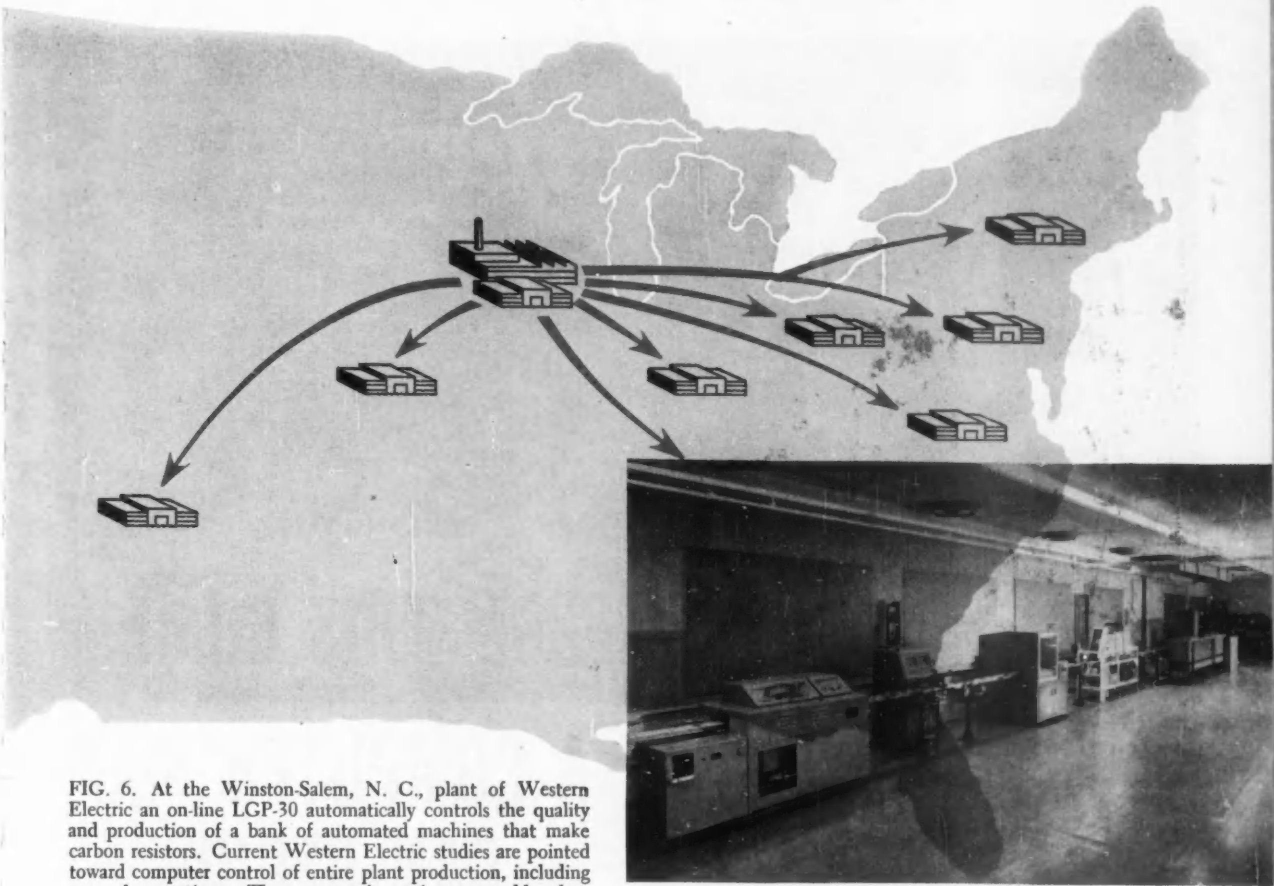


FIG. 6. At the Winston-Salem, N. C., plant of Western Electric an on-line LGP-30 automatically controls the quality and production of a bank of automated machines that make carbon resistors. Current Western Electric studies are pointed toward computer control of entire plant production, including manual operations. The company's engineers would subsequently look to automatic integration of the production of other plants in the same region of the country and some day to participate in the linking of Western Electric and the Bell Telephone System into one automatic manufacturing and supply system.

Automatic systems engineering is where you find it

Practically without exception a combination of user, consultant or contractor, and maker join in the job. Contrary trends exist, one to the end that the systems maker will engineer those systems in which knowledge of the thing to be controlled is common, and the other in which the systems user will predominate because he holds closely the necessary knowledge. The closer applications get to productive, directive, and creative operations that determine one user's competitive edge over another, the more closely the user will draw systems engineering into his own engineering departments. Consequently the further it will move away from the maker of automatic systems. A current example is the chemical processing industry, in which processing techniques and formulations are the hard won competitive edges. Because any major process improvements through improved automatic systems directly affect the edges, the chemical processor's engineers are taking over more and more of the systems engineering.

Major machinery manufacturers are beginning to dominate the specification of their automatic systems because their responsibility for satisfactory operation of the whole automatic metalworking system increases with its extent of information and control.

While the steel industry will continue to rely on outside control specialists, it is tending to develop its own information systems. This is particularly true where entirely new measuring means are required, and where extensive process testing is underway for formulation of control functions. The basic reason is not the wish to increase a competitive edge, for there are few processing secrets in the basic steel industry. The reason is a very practical engineering one: the steel manufacturers have the processes and the requirements for uncommon information systems. Nevertheless, once they have thoroughly formulated the information and control system problems, they will continue to turn to suppliers for detailing the system hardware.

How Reliable are Relays . . .

. . . is a recurring question in this day of production dependence on complex switching systems. To find out which type or make of relay is most dependable, many users exercise groups of relays and keep track of failures. The problem is to devise a circuit that tests each relay in an identical manner and clearly indicates failed contacts. To get a relay manufacturer's views on the subject, author Ledgerwood interviewed Allen-Bradley Co.'s research personnel. They pointed to a user-designed test circuit that not only did not load all relays uniformly but also obscured failures that occurred at certain contacts. Any comparative data obtained with this circuit is useless. This article shows the faults in the defective circuit and goes on to describe several A-B recommended schemes for checking relay electrical reliability. A future article will give hints for improving relay system dependability based on experimental data gathered by Allen-Bradley.

BYRON K. LEDGERWOOD
Control Engineering

The banks upon banks of relays used in complex systems that control all sorts of manufacturing equipment and processes make relay reliability a critical factor for control system designers and users. So critical, in fact, that many users set up relay evaluation programs to determine which types and brands of relays are most reliable for their particular application. Two points are important: 1) what is meant by relay reliability, and 2) what kinds of circuits can be devised that can check the relative reliability of different commercially available relays.

Relays can fail electrically or mechanically. An electrical failure is one in which a contact fails to make, break, or provide continuity; coil faults are considered to be mechanical failures. Mechanical failures are usually at least semipermanent in nature —either part of a relay or a whole relay must be replaced, but they are usually fairly easy to locate. In addition, the expected mechanical life of modern industrial control relays is up in the millions of cycles, so that mechanical reliability is often not the major problem. But electrical failures are something else again; a particle of dirt may prevent a contact from making at any given operation, but if tried again, the contact may clear and work perfectly. From the viewpoint of the user, however, the result of either type of failure may be the same: the cost of finding and repairing the failure may be small compared to the cost of the shutdown. The problem, then, is to determine how to test for the relative electrical reliability of different relays, how to find out how many times they fail to operate properly in a given number of cycles.

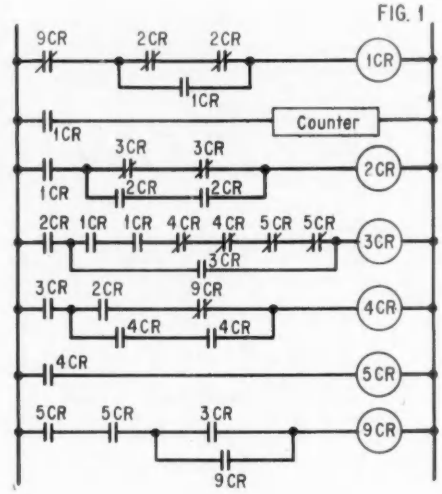
For a fair comparison two conditions must be met: 1) the contacts on the various relays must be subjected to similar loads, and 2) the test circuit must stop on a failure in a manner that will permit the faulty contact to be located. A contact may make or break a circuit or operate dry (carries current but does not make or break a circuit—an interlock, for example). Dry circuit operation is much more difficult for a contact, since the making or breaking process offers a better chance of burning away contamination on the contact surfaces. For this reason, corresponding contacts should be used for corresponding applications on the relays being tested.

Relay test circuits are either of the *chain* or *parallel* variety. In a chain circuit the relays operate continually in sequence, some combination of contacts energizing successive relays, until a failure occurs. In a parallel circuit all of the relays under test are energized and deenergized together, continuing until a failure stops operation. Each technique has its advantages and limitations. The following describes two chain circuits and two parallel circuits. Only one of the chains is recommended; the other is shown as an example of a circuit that yields useless data.

OPERATING SEQUENCE

1. 1CR picks up through a NC contact on 9CR and two NC contacts on 2CR; also, one of 1CR's NO contacts parallels the NC contacts of 2CR, and 1CR is held in over its own contacts
2. An additional NO contact on 1CR makes the circuit to coil of 2CR through two NC contacts of 3CR; also, when 2CR picks up, it locks in through two of its NO contacts which, in series, parallel the NC 3CR contacts
3. In a similar manner 3CR picks up through an additional NO contact on 2CR and closes through two NO contacts on 1CR, two NC contacts on 4CR, and two NC contacts on 5CR; also, when 3CR closes, these contacts, except NO 2CR, are paralleled by a NO contact on 3CR
4. The remaining relays operate successively until 9CR is reached at which time the chain repeats

FIG. 1



1. Defective chain circuit

A properly designed chain circuit has the advantage that the position of the various relays when it stops gives a clear indication of where to look for the faulty contact. This is not true of the parallel circuits where a voltmeter is needed to find the trouble.

The chain circuit of Figure 1 was employed by a large user of industrial control relays to test for electrical reliability. But it is entirely unsatisfactory for this job, since corresponding contacts of the different relays are not loaded similarly, and the failure of certain contacts can set up smaller chains operating within the larger chain rather than stopping the sequence.

In all of the steps described in the operating sequence accompanying Figure 1, the circuit is actually made by a NO contact on the preceding relay. Also, this same contact generally opens the circuit to the relay. Thus this contact makes and breaks relay coil current, tending to keep itself clean. However, those contacts in series with this NO contact neither make nor break the circuit, nor for that matter do the paralleling or lock-in NO contacts of the relay being actuated. These are dry circuit contacts and so are being tested differently than those that make and break the relay coil circuit.

This circuit has additional faults as well. For example, if the NO contact of 3*CR*, which parallels the series combination of NO 1*CR*'s and NC 4*CR*'s and 5*CR*'s in the 3*CR* circuit, fails to make, then the instant 4*CR* picks up, 3*CR* will drop out and open its NO contacts. In turn, 4*CR* will drop out when the NO on 3*CR* opens, and 3*CR* will pick up again when the NC on 4*CR* closes. This chattering of 3*CR* and 4*CR* will continue until the NO 3*CR* contact makes securely or something else happens. Similar troubles can occur if one of the 2*CR* NO contacts in the holding circuit of 2*CR* fails to make.

If one of these "short chain" operations happens to be seen, the failure might be detected; otherwise the circuit will give no indication of a malfunction.

Of the dry circuits only the two NO 1*CR*'s (in 3*CR* circuit) and the single NO's of 2*CR* (in 4*CR* circuit) and 3*CR* (in 9*CR* circuit) will stop the chain by not making. On the other hand, all the NC's can similarly stop it, and relays 4*CR* and 5*CR* really have no dry NO contacts while each has two dry NC's. It is not hard to see, for example, why most failures of 5*CR* are due to NC contacts. As discussed, the dry NO contacts in the holding circuits of 1*CR*, 2*CR*, and 3*CR* can only cause chatter and cannot stop the chain.

2. Recommended chain circuit

A fundamental unit of a chain circuit that gets around the faults of the previous circuit is shown in Figure 2. This unit can be used to form a chain for any even number of relays from eight up by picking the total number of relays n and developing the units as p ranges from one to n. The colored figures on Figure 2 give the contact identification for p equal to nine in a chain where n equals 12. This can be compared with the complete 12-relay chain circuit shown in Figure 3. The nomenclature used in this circuit is somewhat unusual. For example, the NC contact of relay 6 in the circuit of relay 1 is called 6*NCc*, differentiating it from contact 6*NCb* in the circuit of relay 2.

The circuit is designed so that the failure of any contact will stop the chain and the faulty contact be indicated by the position of the relays. In addition, each relay is subjected to identical loading conditions. In every case *NOa* and *NCb* are dry, *NCc* breaks coil sealed current, and *NOd* makes coil inrush current.

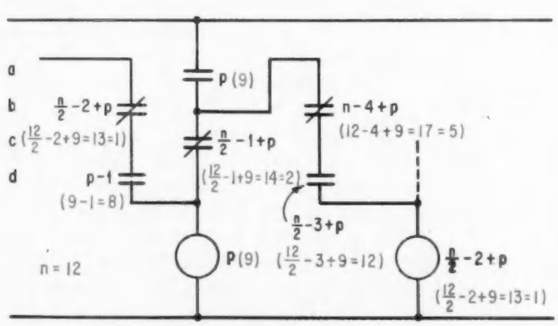
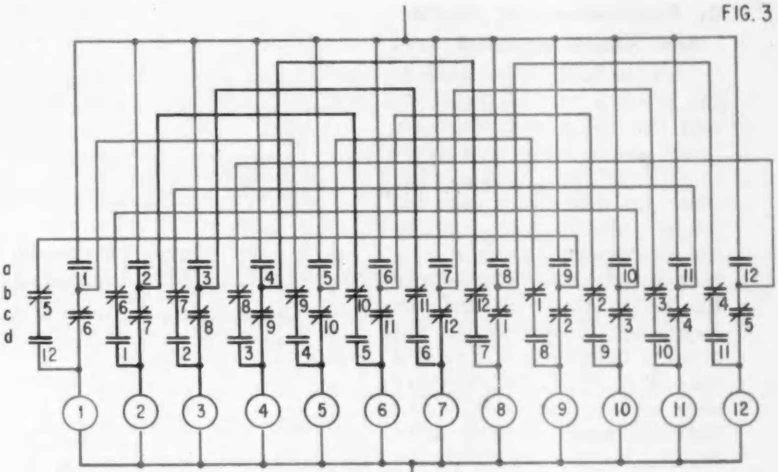


FIG. 2 FUNDAMENTAL CHAIN CIRCUIT UNIT

FIG. 3



Dead leads in black
Live leads in color

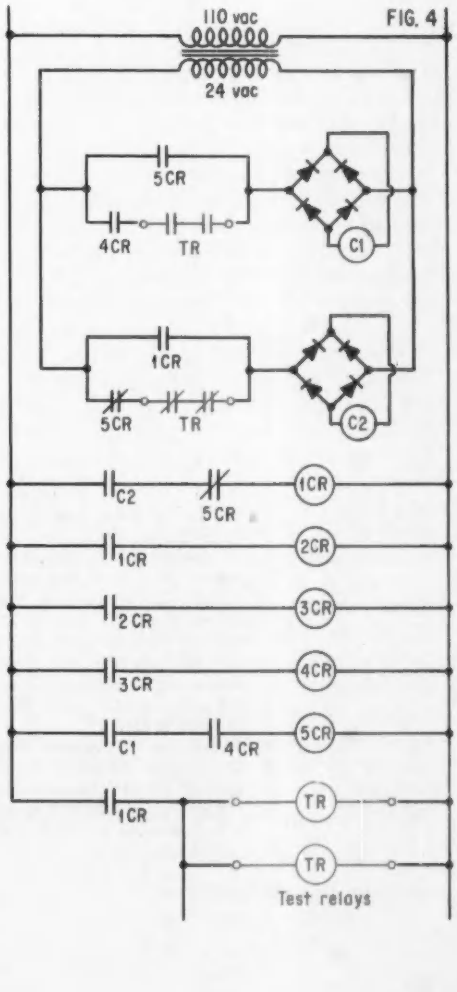
OPERATING SEQUENCE

1. Assume initially that relays 1, 2, 3, 4, 5, 6, and 7 are deenergized and relays 8, 9, 10, 11, and 12 are energized
2. 1 picks up through 12NOd, 5NCb, and 9NOa and holds in through 6NCc and 1NOa (this is the condition indicated by colored and black leads)
3. 1 then picks up 2 through 1NOd, 6NCb, and 10NOa and drops out 8 by opening 1NCc; 8 cannot stay in because 7NOd is open; 1NCb cannot drop out 9 because 2NCc and 9NOa are closed
4. The dropping out of 8 has no effect on any other relay; 8NOa, opening, holds 8 open but cannot drop out 12 through 11NOd and 4NCb because 12 is held in through 5NCc and 12NOa; 8NCb, closing, cannot pick up 4 because 3NOd is open; 8NCc, closing, cannot pick up 3 because both 6NOd and 3NOa are open; 8NOd, opening, cannot drop out 9 because 2NCc and 9NOa are closed
5. Similarly, 2 picks up 3 and drops out 9 and so on

3. Recommended dry circuit parallel test

Operating the relays under test in a parallel manner has certain advantages. Since all of the relays operate at the same time, there is no chance of vibration caused by one relay influencing a contact on another relay. In addition, contact current is independent of coil current so that the contacts can be checked under any desired condition. It also appears simpler to mount the relays in one horizontal line when they are tested in parallel, removing any effect of mounting one relay over another.

The circuit of Figure 4 can be used for dry circuit testing any number of relays. None of the test relay (*TR*) contacts make or break a circuit. If one of the contacts fails to make, the automatic sequencing will stop. A voltmeter is needed to locate the faulty contact.



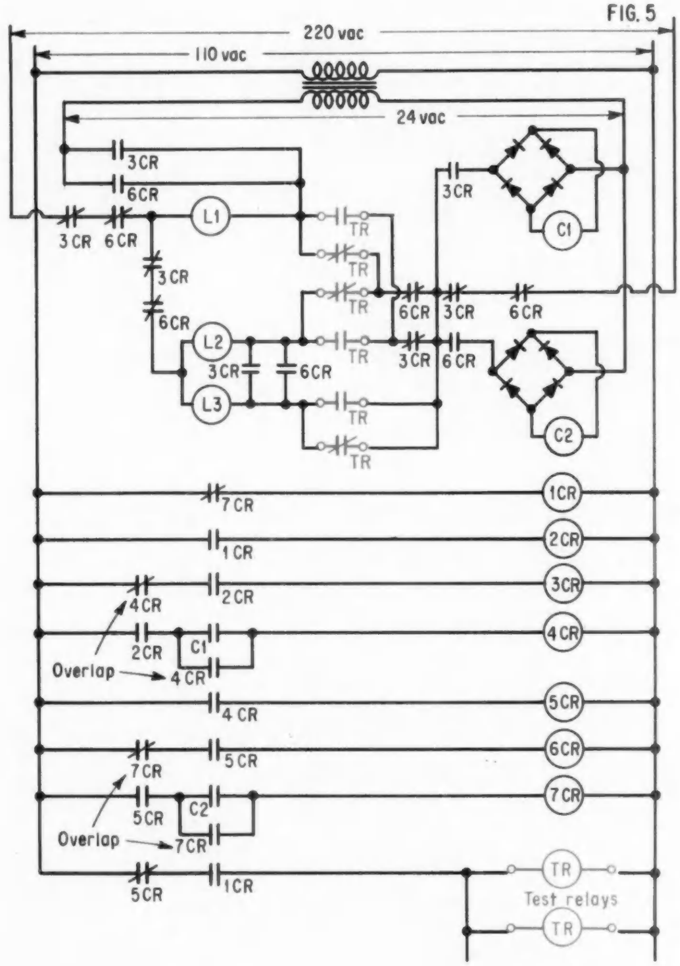
OPERATING SEQUENCE

1. **Test relay's NC contacts are checked;** C2 picks up through NC contact of 5CR and the NC contacts of TR
2. NO contact of C2 picks up 1CR through NC contact of 5CR
3. NO contacts of 1CR hold in C2 and pick up 2CR and test relays TR
4. TR's NC open dry and TR's NO close but do not make circuit through C1; NO contact on 2CR picks up 3CR
5. NO contact on 3CR picks up 4CR
6. NO contact on 4CR sets up circuit for 5CR; **NO on 4CR closes checking test relay's NO contacts;** C1 picks up through NO contact of 4CR and NO contacts of TR's
7. NO contact on C1 picks up 5CR through NO on 4CR
8. NC contact on 5CR drops out 1CR; NO contact on 5CR holds in C1
9. NO contacts on 1CR drop out C2, 2CR, and TR's
10. NO contact on 2CR drops out 3CR; NO contacts on TR's open dry, and NC contacts on TR's close but do not make circuit through C2
11. NO contact on 3CR drops out 4CR
12. NO contact on 4CR drops out 5CR
13. NO contact on 5CR drops out C1; at this point none of the coils are energized, and all relays are either down or dropping out
14. NC contact on 5CR sets up circuit for 1CR; **NC contact on 5CR closes checking NC's on TR's,** and cycle repeats

4. Recommended make and break parallel test

This is similar in principle to the previous parallel circuit except that the relay contacts are tested under make and break conditions. The relays under test break (or make) 220 volts impressed across their normally closed (or normally open) contacts and the load. Circuit continuity is then checked by impressing 24 volts across the contacts under test and the coil of relay C1 or C2. If the latter relay picks up, then the test relay contacts have made properly. This circuit has the same advantages as that shown in Figure 4. It will stop if any contact fails to make, but again a voltmeter is required to locate the faulty contact.

FIG. 5



OPERATING SEQUENCE

1. 1CR is energized picking up test relays TR which break 220 volts on their NC contacts and make 220 volts on their NO contacts
2. 1CR picks up 2CR, and 2CR picks up 3CR; 3CR takes off 220 volts and applies 24 volts to test relay NO contacts in series
3. **If test relay NO contacts have made properly, 24 volts picks up C1**
4. C1 picks up 4CR; 4CR drops out 3CR and holds itself in; 3CR takes 24 volts off TR's NO contacts and applies 220 volts in parallel
5. 4CR picks up 5CR; 5CR drops out test relays breaking 220 volts on NO contacts and making 220 volts on NC contacts
6. 5CR picks up 6CR which takes 220 volts off TR's NC contacts and applies 24 volts in series
7. **If test relay NC contacts have made properly, 24 volts picks up C2**
8. C2 picks up 7CR which holds itself in and drops out 6CR; 6CR takes 24 volts off TR's NC contacts and applies 220 volts in parallel
9. 7CR drops out 1CR; 1CR drops out 2CR; 2CR drops out 4CR; 4CR drops out 5CR; 5CR drops out 7CR; 7CR picks up 1CR
10. Cycle begins again

a comparison of

Integral and Incremental Digital Computers for process control applications

THE GIST: The suitability of a digital computer for a particular control application depends on such factors as computation speed, logical and mathematical capabilities, input-output requirements, and reliability and maintainability. Integral and incremental computers each have inherent and distinctive design and operational features; these play a significant role in the evaluation of computer suitability.

EDWARD L. BRAUN, Genesys Corp.

One criterion for classifying digital computers is by the nature of information transmissions on their internal communication lines. Using this criterion, general purpose (GP) computers are classified as integral transfer machines and digital differential analyzers (DDA) as incremental transfer machines. Each type may have a variable or fixed program depending on its application: general or particular.

Integral computers

The integral transfer computer solves problems by procedures similar to those used by a person operating a desk calculator. The digital computer, however, performs all computing and data transfer operations at high speed and stores and executes a complete program without interruption.

A simplified information flow diagram for an integral computer is shown in Figure 1. Initial values, measured variables, constants, and a detailed program are entered in the main storage unit. The main store usually has a capacity of thousands of words, each word consisting of about 20 to 40 binary digits. Single items of data are taken from this store, operated on individually, or combined mathematically or logically with another item of data taken from the arithmetic unit; and the result is either left in the arithmetic unit for further processing, returned to the store, or transferred to some piece of output equipment. The control unit establishes transmission paths between the store, arithmetic unit, input-output equipment, and its own sequence control.

To facilitate programming, the machine executes a variety of arithmetic, logical, and data transfer instructions. The codes for instructions are interpreted and cause the generation of specific operations required in the execution of each instruction by means of the decoding and encoding function tables. Instructions and operands are taken from the main store in accordance with the contents of the instruction address counter and the operand address register, respectively.

Two aspects of integral transfer operation add to the time required to execute a program. The first is that in operating on continuous variables, the arithmetic unit performs a considerable amount of redundant computing: it does not utilize the result of the same type of operation on the preceding value of the variable. The second aspect is that when using a dynamic type of main store (such as drum or disc memories), appreciable time is consumed in waiting for access to specific storage locations.

To perform the operation of multiplication in an integral computer (for example, to form AB) A and B must each be selected from the main store and directed to the proper register (A) in the arithmetic unit, a complete multiplication performed, and the result transferred back to some location in the main store. Thus considerable transfer of data occurs within the integral computer, compared with the simplicity of multiplication in the incremental computer.

Incremental computers

The incremental computer performs its basic op-

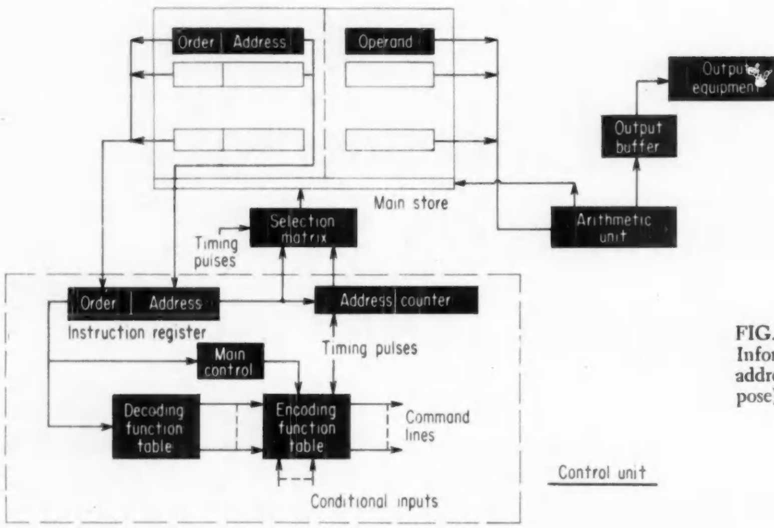
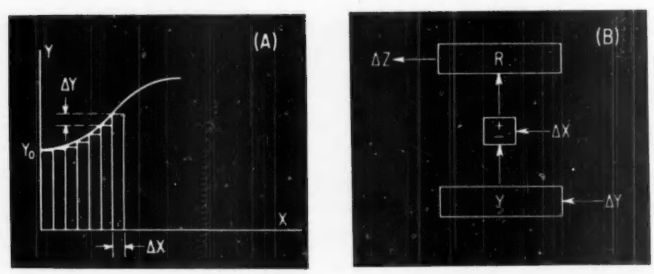


FIG. 1.
Information flow in a single address integral (general purpose) computer.

FIG. 2.
In an incremental computer, integration is performed by serial summation. The change in Y, ΔY, is added to the contents of the Y register. Under influence of the ΔX pulse, the Y register contents are added to the R register. The R register overflow, ΔZ, when summed, approximates the integral.



eration, serial summation, in such a manner that it approximates the process of integration, Figure 2A, to any desired degree of precision within the machine's capacity. Here:

$$\int y dx \cong \Sigma Y \Delta X$$

The basic integrator, Figure 2B, consists of two registers, R and Y. The contents of the Y register—the initial value Y_0 plus the summation of the ΔY input pulses—are added to or subtracted from the R register under control of the ΔX pulse. The output of the R register is its overflow ΔZ, and the integral is then the summation of the ΔZ pulses:

$$\Sigma \Delta Z = \Sigma Y \Delta X \cong \int y dx$$

The incremental computer contains digital capacity to form many such operational integrators, Figure 3. The solution of any problem involving continuous variables is accomplished by specifying an interconnection of integrators which simulates the interrelations of variables in the equations being solved. (All other operations like multiplication, division, function generation, and differentiation required in the course of solution are derived by causing specified combinations of variables to enter operational units as in analog computers.)

In keeping with a serial mode of operation, each integrator functions in turn and then idles while another integrator functions. Even if the Y and R registers are formed from active elements (flip-flops or binary counters), during any computation period the states of all integrator elements would remain unchanged, with the exception of the integrator currently being operated upon. This fact, plus the availability of an economical passive storage system like a magnetic drum or disc memory, leads to an important advantage: passive storage cells may be substituted for the active storage elements without any degradation of performance. Accordingly, individual integrators are formed from pairs of words, the Y and R registers, stored in two long delay lines on a magnetic surface. The rules for operating on these registers are stored in relatively simple control logic circuits. In Figure 3, as the magnetic surface rotates, successive bits of each integrator appear at the read heads, are operated on according to the rules built into the control circuitry, and the results are returned to the magnetic store.

In a DDA the central store, the *dz* store, holds the up-to-date outputs of all operational units. Its capacity is determined by the number of operational units in the machine and the number of bits required to represent the incremental outputs of these

units. Usually the size of the dz store is less than a few hundred bits.

In large measure, economies are effected in the DDA by the establishment of a simple, ordered arrangement of data and a relationship throughout the machine between each item in storage and the times within a major or minor cycle that the item is accessible to one or more read heads. There is zero access time to the dz store for the recording of each operational unit's output because outputs are always recorded at a specified time near the end of the active period of each unit. Since these times are fixed and predeterminable, a correspondence can be established between them and specified positions in the central store.

The times at which specific items in the dz store will be accessible to fixed read heads is ascertainable from the knowledge of when these items were recorded and the store's delay characteristics. In practice, one or more dz read heads are so placed that all specified inputs to an operational unit can be read during the active period of the preceding unit. Therefore when an integrator's active period begins, all information required from the dz store has already been selected and made available to the integrator. Thus there is zero access time for reading data from the dz store.

The control logic for selecting items from the central dz store is also simple. The inputs to each integrator consist (except for inputs from external sources) simply of the outputs of certain specified integrators within the machine. Any one of these outputs, stored in the dz central file, can serve as the dx input to an integrator and one or more of them constitute the Σdy input. To determine the value of dx for any given integrator, then, it is only necessary to read the appropriate cell in the dz central store; to determine Σdy, it is only necessary to read the dz central store and sum all dz's that, in total, constitute the Σdy input to the integrator.

If the machine contains a small number of integrators (less than the number of bits per integrator), the entire contents of the dz store can be read from a single read head during the integrator's active period. For many integrators the entire contents of the dz store can still be read during a period corresponding to the length of a single integrator by using a number of heads suitably placed along the dz line. In either case, specific items in the store can be selected by the detection of coincidence between marker pulses in one or more address channels and the binary contents of each dz storage cell.

Decoding markers serve two important functions. First, they specify which integrator input and output "lines" are to be interconnected. In this way they are equivalent to the physical wiring and plugboard arrangement interconnecting integrators in an analog computer. Second, in conjunction with simple decoding circuitry, they cause the value of items in the central dz store to be sensed and selected.

A unique feature of the DDA is that the result of a previous computation is always stored, and only incremental adjustments to the result are generated during succeeding computation periods. This mode of operation reduces the complexity of information transfer operations, for only increments rather than whole numbers have to be transferred internally and, as pointed out, these relatively simple transfers are done in a fixed, systematic manner.

As an example, consider the operation of multiplying changing values of A and B. This can be represented by:

$$(A + \Delta A)(B + \Delta B) = AB + (A\,\Delta B + B\,\Delta A + \Delta A\,\Delta B)$$

So the incremental computer merely must form $\Delta(AB) = (A\,\Delta B + B\,\Delta A + \Delta A\,\Delta B)$ and add it to the previously computed product AB. If a trapezoidal integration scheme is employed, only one integrator is required to form each of the following two terms:

$$(A + \Delta A/2)\Delta B \text{ and } (B + \Delta B/2)\Delta A$$

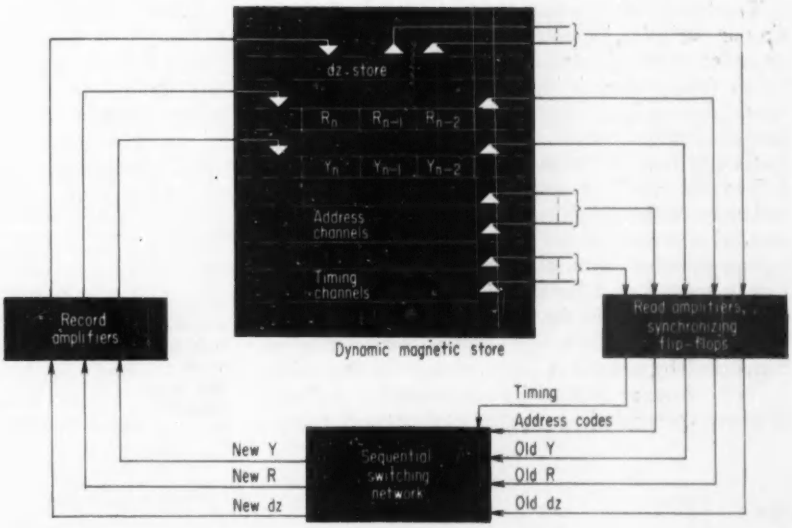


FIG. 3.
Information flow in an incremental (DDA) computer.

The sum of these terms is: $A\,\Delta B + B\,\Delta A + \Delta A\,\Delta B = \Delta(AB)$. Thus the product is formed by a simple addition process in two integrators and the summation of the outputs of these integrators.

CRITERIA FOR CONTROL APPLICATIONS

The design and operation of integral and incremental computers determine how well they meet certain criteria for control applications. Among the important considerations are computer speed, logical and mathematical capabilities, input-output requirements, reliability, and maintainability.

Computer speed

The speed of a digital computer for control applications can itself be measured in terms of two important criteria: computation frequency and slewing time.

• **Computation frequency**—is the reciprocal of the time required for a single iteration of a computational program. It determines the maximum frequency component and bandwidth of input data to which the computer can respond. This bandwidth is, in practice, approximately one-eighth to one-fourth the computation frequency.

It is difficult to make a general comparison of the computation frequency capabilities of integral and incremental transfer computers. Even for two specific machines the comparison is affected by the particular mathematical formulation and program employed for problem solution. To provide a guidepost, however, the table lists some representative figures for the time required to carry out certain basic arithmetic operations in incremental and integral transfer machines. It is assumed that both machines use a magnetic drum or disc memory as the main store. The value of n in the table is usually between 15 and 20 word times. The access time, with minimum-access programming, is usually between 5 and 10 word times. Programs for generating the sine or cosine may require about 20 to 30 simple operations like addition and internal transfers of data and about six multiplications.

The table indicates that for computations on continuous variables, incremental computations are about an order of magnitude faster than integral computations. This feature is important in a control system where time delays introduced by the computer can lead to system instability. The computation frequency of the incremental machine would be about 100 to 200 iterations per sec—satisfactory in control systems with bandwidths of 0 to 25 or 50 cps. The integral machine would have a computation frequency of about 10 to 20 iterations per sec—satisfactory in systems with bandwidths of 0 to 2.5 or 5 cps.

• **Slewing time**—is the time required for a computer to progress from one state to a new state as demanded by a sudden, large change in the value of one or more inputs. To generate a problem solution corresponding to the new sets of values of the input variables, without introducing a large time lag, the computer must be able to generate large changes in a variable during each iteration period.

An integral machine requires only one computation period for the effects of a change (no matter how great, provided it is within the capacity of the machine) to be recognized. Here slewing time is not related to accuracy, although the number of computation periods required for a problem solution does depend to some extent on the accuracy required and the nature of the problem.

In an incremental machine the slewing time depends on the number of increments to be generated. The number of increments depends, in turn, on the magnitude of the change and the scale factor of the variable. In a single-increment computer the number of computation periods increases in inverse proportion to the allowable error or precision, because allowable error determines the scale of the independent variable. Therefore, one can obtain adequate precision at the cost of a relatively large number of computation periods for the solution of a given problem. Generally speaking then, as far as slewing time is concerned, an integral transfer machine is superior to an incremental machine.

Certain modifications can be made in incremental machines to reduce slewing time. In early DDA's no more than a single increment could be generated by an operational unit during each computation period. Accordingly, for control applications the computation period was chosen sufficiently small so that under normal dynamic operation the input variables of the controlled device would not change by more than a single increment during this time. That is, the fixed slewing rate was made roughly equal to the normal rate of change of the variables.

Situations can arise, however, where the values of one or more variables change abruptly. In this case a slow slewing time introduces a lag and a serious dynamic error. The slewing rate limitation, serious only in relatively high speed control appli-

Word Times for Basic Arithmetic Operations

Operation	Word times for execution	
	Incremental	Integral
Add, subtract	1	1 + access time
Multiply	2	n + access time
Divide	4	n + access time
Sine, cosine	1	Function of numerical approximation
Integrate	1	Function of numerical approximation

cations, can be alleviated by increasing the increment size, i.e., reducing the scale factor whenever a large slewing rate becomes necessary. One way of doing this is to provide a register which accumulates the difference between the value of a variable stored within the machine from a preceding measurement and the new value entering the machine. When this difference exceeds a predetermined amount, a signal can automatically be generated causing the entire machine to operate at a reduced scale factor (with larger increments) until the difference in the register drops below the predetermined level and returns the machine to the normal increment rate.

Instead of a single, fixed increment rate, one can incorporate a number of slewing rates, each brought into play when the difference between the actual and desired values is within each of certain predetermined ranges. The effect of having several slewing increments is shown in Figure 4. Graph *A* shows the response of the integral transfer computer which requires only one computation period for slewing time. Graph *D* shows the response for a fixed increment computer which takes 25 computation periods to change the required 25 increments of the input variable. Graph *C* shows the response for an incremental computer having a normal fixed increment and a slewing increment equal to 16 times the normal increment. In this case the response time is reduced to 10 computation periods. Graph *B* shows the response time when two slewing increments, one 16 times and the other four times the normal fixed increment, are made available. In this latter case the response time is only four computation periods, a significant reduction in slewing time, but of course at the added expense of equipment to produce the variable slewing rates.

The problem of generating a number of increments corresponding to a change in a variable within a minimum number of computation periods by accumulating different standard sized increments is analogous to the problem of determining the unknown weight of an object with a minimum number of trials. The unknown value is most rapidly determined if each member of the standard set of weights is a member of a geometric progression with a common ratio of two. The value of the largest increment should be at least one-half the minimum anticipated unknown, and the value of the smallest depends on the desired measurement precision.

The variable increment slewing operation is controlled as follows: each input to the machine is compared with the corresponding input received during the preceding period. The largest increment size less than this difference is then selected and added to the input from the preceding period, and the new value is stored for use in the succeeding period. Simultaneously the computation is updated by an amount corresponding to the chosen increment. The procedure is repeated until the output is an exact solution of the problem.

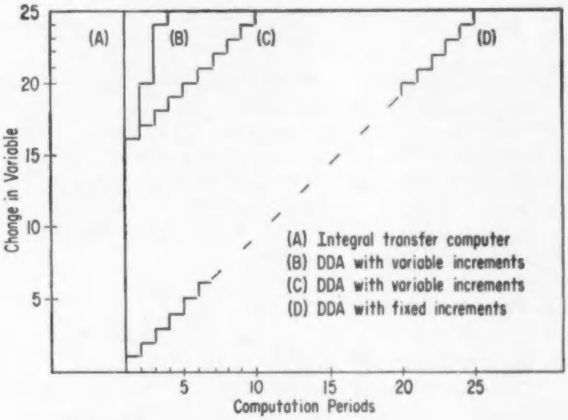


FIG. 4.
Response times of different computer mechanizations. Using variable slewing increments in the incremental computer, graphs B and C, decreases the slewing time.

Logical and mathematical capabilities

The relative merits of integral and incremental transfer machines differ for three different types of information processing procedures: computations on continuous variables, decision making, and data processing.

• **Computation on continuous variables**—The incremental machine can perform numerical integration as well as algebraic and trigonometric operations on continuous quantities in less time and with less equipment than a comparable integral transfer machine. This capability, based on the fact that in any given period it utilizes information generated in the preceding period, can be capitalized on in control systems where the quantities are continuously variable and limited in excursion and rate.

• **Decision making**—If a computer is to schedule different computations to provide overall supervisory control, it must be able to make timely decisions based on logical considerations and to call for different individual computations as required. An integral transfer machine can initiate a new computation after only one computation period, thus introducing no significant time delay. The incremental machine, on the other hand, may require a large number of periods. Thus, though the incremental machine has no intrinsic difficulty in making a decision, it may introduce significant lag in implementing the decision. If it does not have the capability to initiate a new computation on demand, then one obvious but uneconomical procedure would be to simultaneously compute all functions that may be required and implement a decision by switching to the functions required. In closed-loop systems, anticipatory circuits which make both the functions and their time derivatives available to provide both error and error rate control may be used to speed decision making of incremental computers.

• **Data processing**—The integral transfer machine

may be used for a variety of general data processing applications, including sorting and collating of digital data and the processing of noisy data of low correlation. The incremental computer is not well suited for these applications nor for problems of logical analysis, because such applications usually involve large changes in the contents of registers in each computation period.

Input-output requirements

Data can be entered into a digital computer in three different forms:

1. Binary weighted pulses whose sum is proportional to the whole or integral value of a sampled input variable. The binary number may be serial in the form of pulse trains in which case each pulse is read sequentially or in parallel in which case all pulses are read simultaneously (integral measure).
2. A number of equally weighted pulses proportional to a change or increment in the input (incremental measure).
3. A pulse rate proportional to the value of the sampled input.

Arrangements are possible that allow data in any of these forms to be used as an input to either type of digital machine. Normally, integral measure (form 1) would be used with an integral machine, whereas either integral or incremental measure (forms 1 or 2) may be used with an incremental machine. An incremental data conversion and transmission system is more economical of equipment and more compatible with the basic nature of an incremental machine. If binary weighted integral input data is used with an incremental computer, special registers, termed servo registers, generate unitary weighted pulse trains from the integral input data. (This is done by subtracting one increment at a time from the contents of a servo register until it is cleared.) Data in this form can then be used as inputs to other operational elements.

A major consideration in selecting either integral or incremental measure is the effect of a permanent offset caused by losing an increment as a result of some system malfunction. The choice will therefore be influenced by the reliability of the data input-output system, and whether it is within a broader closed loop with zero steady-state error or within a system where new absolute references can be inserted at specified intervals.

Variable pulse rate data (form 3) is obtainable, for example, from certain types of pressure and flow meters. This data can readily be converted to binary weighted representation by accumulating, within a counter, the pulses received over some specified interval.

Output signals in the form of integral numbers can be obtained from incremental as well as integral transfer machines, since storage registers are available for accumulating incremental quantities. Output signals in the form of incremental quantities may also be obtained from either type of machine since in an integral transfer machine, increments may be obtained by forming the differences between successive outputs.

Reliability and maintainability

Because large economic losses would be incurred by shutdowns of a process control operation, equipment reliability is of prime importance. Basically system reliability depends on good electrical and mechanical design. Straightforward and uncomplicated logical design, the availability of test programs, and special test facilities all contribute to good maintainability.

• **Reliability**—one measure of reliability of a computing system is the time interval over which the system operates satisfactorily. Two factors affect the reliability of a digital computer, namely malfunctions and failures. The malfunction is a temporary disturbance producing an error which may or may not propagate through the system. The failure results from a permanent change in the characteristics of a component such that it no longer satisfies the demands of its circuit.

The incremental machine has fewer failures simply because it has fewer components than a comparable integral machine. Also it has fewer malfunctions. However, malfunction errors may have widespread effect because the error may occur in time-shared equipment, and because the effect of an error may persist for a long time since in the incremental computer, new computations always utilize old data. Some malfunctions may cause only negligible trouble as in the cases where only one increment is affected or a relatively insignificant variable is altered.

In the integral computer most malfunctions cause only a temporary disturbance because, in general, the computations in one period are independent of those in the preceding period. It is only where the problem being solved needs data retained for more than one period that errors are not promptly removed.

• **Maintainability**—refers to the ease with which an existing fault may be found and corrected. The maintainability factor of an incremental machine is reduced by some of the logical devices used in its design, usually centering about a greater use of time-sharing. However, the degree of time-sharing employed can always be reduced at the cost of additional components. Also, additional equipment can be added to the basic incremental machine to provide improved error-detecting capabilities. But adding such equipment then leads to reduced reliability. The maintainability of an integral machine is adversely affected by its large number of components. On the other hand, it can provide elaborate checks on itself and the control system in which it is incorporated by the availability and relative ease of interpreting step-by-step operation, special program control features, as, for example, a break point facility and diagnostic and test programs.

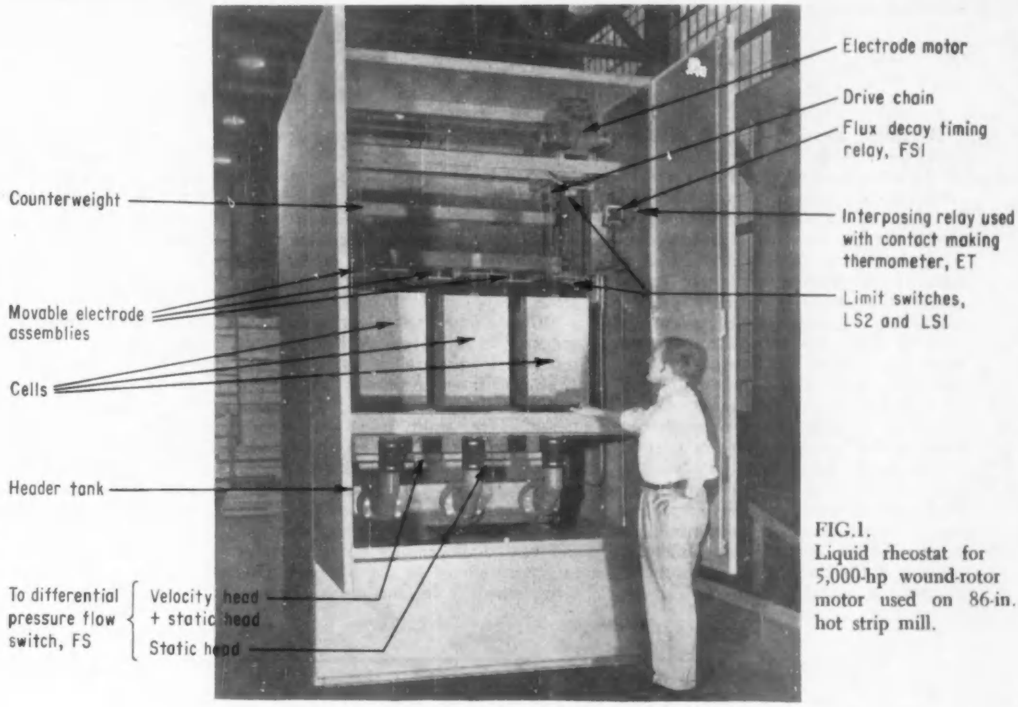


FIG. 1. Liquid rheostat for 5,000-hp wound-rotor motor used on 86-in. hot strip mill.

Protecting Liquid Rheostats

IRVIN J. GLADNIK
Allis-Chalmers Mfg. Co.

THE GIST: The increasing use of the wound-rotor motor/liquid rheostat combination for speed control of pumps and fans and for the load regulation of large flywheel motor-generator sets has placed added emphasis on the protective features that may be needed. Author Gladnick points out the key variables that affect optimum liquid rheostat performance and shows how the system monitors these variables. The liquid rheostat as a control system component is briefly reviewed on the next page.

The problem of protecting a liquid rheostat divides into three parts: 1) making sure that system conditions are satisfactory before the motor and rheostat are put on the line, 2) shutting down the system if an objectionable condition occurs during operating, and 3) notifying the operator of system shutdown and of incipient conditions that might cause future shutdown if allowed to continue. Starting and running protection are obtained by interlocking with control of the wound-rotor motor circuit breaker; an annunciator alerts the operator.

Figure 1 shows a liquid rheostat for a steel mill drive, illustrating the physical location of system components and some of the protective features on a typical unit. Electrolyte and cooling water flow, together with the safety devices associated with these flows, are represented in Figure 2. The schematic of Figure 3 gives the simplified control scheme for a liquid rheostat, emphasizing the protective features and defining the symbols.

Starting protection

Before the motor circuit breaker can be closed, the following conditions must be met as indicated by the "Starting" box in Figure 3:

- electrolyte must be flowing in the closed system
- liquid rheostat movable electrode assembly must be in its maximum resistance position
- temperature of the electrolyte flowing into the liquid rheostat must not be lower than 70 deg F
- ac and dc power supplies must be energized
- cooling water must be up to pressure.

Liquid Rheostats as Control Components

A liquid rheostat controls actuator speed by varying the external resistance in the rotor winding circuit of a wound-rotor motor. This is accomplished by simultaneously changing the distance between the movable and stationary electrodes, as well as the level of the electrolyte. The continuous stepless resistance characteristic is well suited for speed regulation in variable torque applications such as drives for induced and forced draft fans, centrifugal pumps, blowers, and compressors and for the regulation of constant current or constant torque drives. In addition, liquid rheostats can serve in the dual role of motor starters.

Two interesting applications are in the control of drives for blooming and slabbing mills and in the control of motors used to start large synchronous machines. In the first of these, a liquid rheostat controls a flywheel motor-generator set driven by a wound-rotor motor. The object is to smooth out the power demands of a drive subjected to the high impact loads occurring in blooming and slabbing mills. A current transformer in the stator of the wound-rotor motor provides a signal proportional to load. This signal feeds a rotating amplifier exciter or a magnetic amplifier that controls the electrode positioning motor of the rheostat.

When a high impact load occurs, the suddenly increased motor stator current acts through the exciter of magnetic amplifier and inserts resistance in the rotor winding circuit of the wound-rotor motor. This limits input power and forces the flywheel of the motor-generator set to give up the additional energy required to carry through the transient. After the peak load is past, the stator current and proportional signal decrease, and wound-rotor motor speed increases to restore energy to the flywheel. This action smooths out the power demand.

In the second application a liquid rheostat controls the acceleration and speed of a wound-rotor motor used to start a large synchronous machine. A proportional signal from the stator current transformer actuates the electrode motor through an amplifier to provide constant torque acceleration of the drive. When the synchronous machine approaches synchronous speed, liquid rheostat control is transferred to a synchro operator which then positions the electrodes by means of electrical impulses. When synchronous speed is reached, the synchro operator connects the machine to the line.

Liquid rheostat control has been applied to wound-rotor motors ranging in size from less than 400 hp to 10,000 hp. With the steadily increasing size of electrical drives, indications are that they will be used to control higher horsepower units in the future.

The electrolyte must be flowing to provide the required starting resistance. This flow is monitored by a differential pressure switch *FS*, an "a" contact of the pump starter *P*, a flux decay timing relay *FS1*, and an auxiliary relay *FS2*. The pressure switch measures the differential between electrolyte static head and the total head consisting of static plus velocity heads. The flux decay timing relay prevents a momentary opening of the pressure switch contacts, *FS*, from tripping the motor breaker. Flow switch protective scheme deenergizes *FS2* if electrolyte flow falls below 75 percent of rated.

Since maximum secondary resistance is necessary to limit starting current and yet provide sufficient starting torque, the motor circuit breaker is prevented from closing unless the liquid rheostat is in its maximum resistance position. When the movable electrode assembly is in the maximum down position (maximum resistance position—note construction of electrode plates in Figure 2), a normally-open contact of limit switch *LS1* is closed, causing relay *LL* to pick up and close a contact in the motor circuit breaker closing circuit.

In the simplified schematic of Figure 3, the up relay *U* is energized when the breaker is closed and the down relay *D* when the breaker is open. In the latter case, relay *D* causes the movable electrode motor to lower the electrode assembly to the maximum resistance position for the next starting cycle. Movable electrode overtravel is prevented by lower limit switch *LS1* and upper limit switch *LS2*, backed up by mechanical stops.

The temperature of the incoming electrolyte should not be less than 70 deg F when the motor circuit breaker is closed even under unusual environmental conditions. The resistance of the sodium carbonate electrolyte increases more rapidly as the liquid is cooled below 70 deg F, so that excessively low temperatures might increase resistance to the point where the motor would not start in the maximum resistance position. To prevent this, an immersion heater is installed in the reservoir of outdoor installations or where climatic, ambient, or load conditions dictate its use.

Here the thermostatic control device has two independently adjustable contacts: normally-closed *IH1*, and normally-open *IH2*. When the temperature is too low, normally-closed contact *IH1* energizes relay *IHX* to operate the electrolyte pump starter and the immersion heater contactor. When the temperature reaches 70 deg F, normally-open contact *IH2* closes in the motor circuit breaker closing circuit and *IH1* opens.

Ac and dc control voltages to the system are assured by interlocking dc voltage relay *UV* and ac voltage relay *UV1* into the motor circuit breaker closing circuit.

To insure that sufficient cooling water is flowing before the motor circuit breaker is closed, a heavy duty mercury pressure switch *CWP* is used in the line.

Running protection

Once the system is on the line, another somewhat overlapping set of operating requirements exist. If the ac or dc control voltage fails or electrolyte flow drops below 75 percent of normal, the circuit breaker is tripped by normally-closed contacts of *UV* and *FS2*. If the temperature of the electrolyte leaving the cells exceeds 130 deg F, a high temperature electrolyte sensing device trips the breaker. This device can be either a contact-making thermometer with interposing relay or heavy duty mercury temperature-sensing switch located in the receiver tank.

Notifying the operator

To alert the operator to trouble, the annunciator alarm circuit is completed when any one of the following conditions occur:

- electrolyte flow drops below 75 percent of normal (by *FS2*)
- either ac or dc control voltage fails (by *UV*)
- electrolyte temperature is high (by *ET*)
- level of electrolyte in reservoir is low (by *ELL*).

The low level electrolyte sensing system consists of a relay, electrode holder, and two electrodes. The relay is closed as long as the two electrodes are in the electrolyte. But as soon as the electrolyte falls below the electrodes, the relay is deenergized.

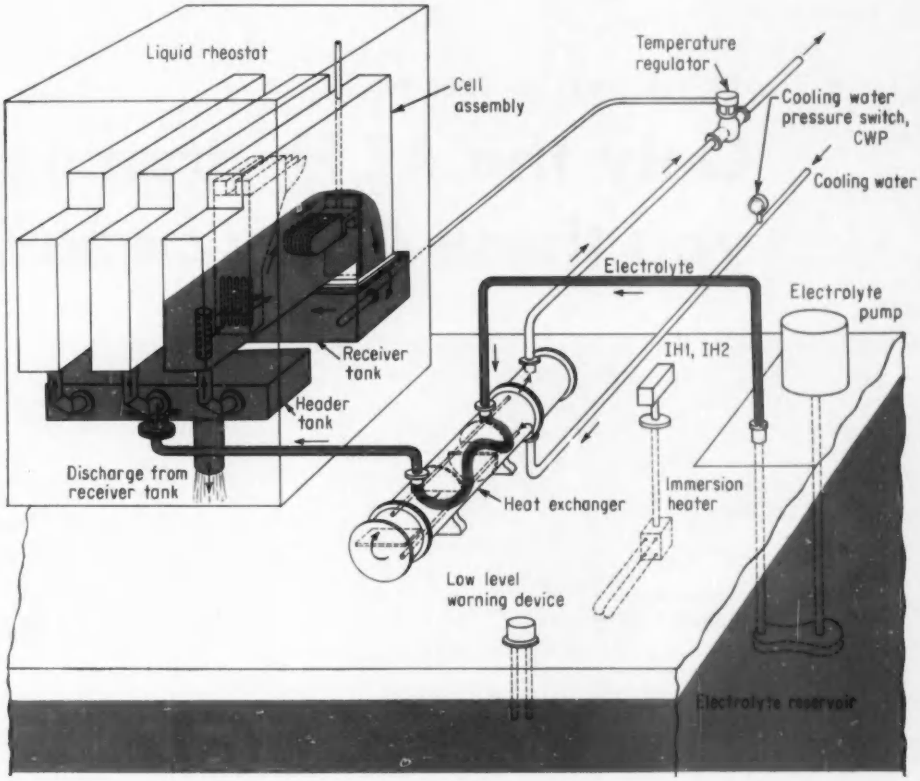
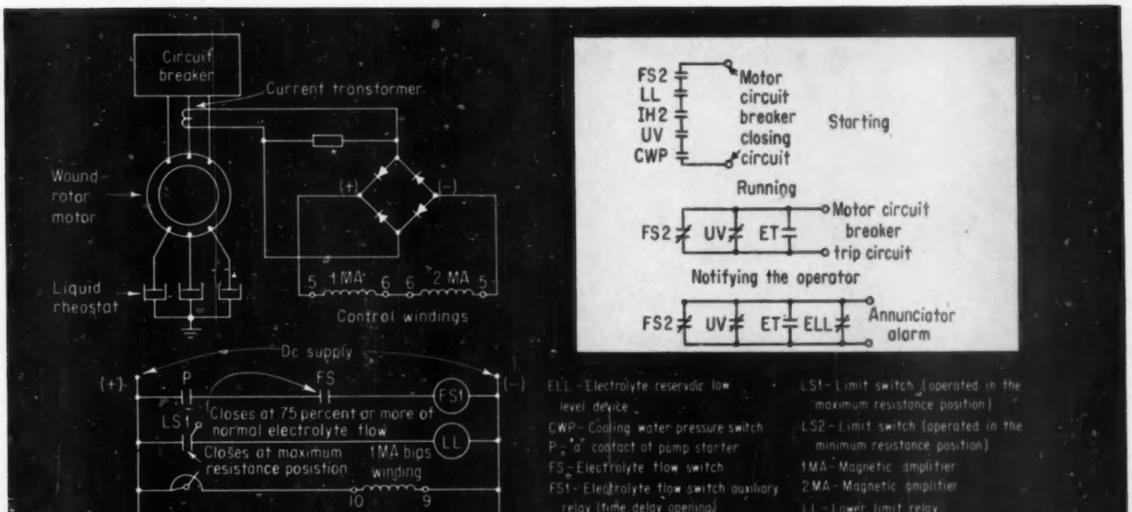


FIG. 2.
Protective devices that monitor electrolyte and cooling water flow.

FIG. 3.
Simplified liquid rheostat control system shows interlocking of protective features.



Analysis and Stabilization of Sampled Data Systems

GEORGE J. THALER
U. S. Naval Postgraduate School
Monterey, Calif.

A sampled data system may be represented by the simplified block diagram of Figure 1. A frequent control problem is that of analyzing the basic loop for stability and stabilizing the system with a cascaded filter G_c not isolated by samples.

Frequency response methods may be applied successfully for simple single loop systems using Nyquist's criterion to check system stability (for more complicated systems, the z-transform methods may be better). In the system of Figure 1

$$\frac{\theta_C^*(s)}{\theta_R^*(s)} = \frac{G^*(s)}{1 + G^*(s)} \tag{1}$$

from which the polar plot of $G^*(j\omega)$ is the obvious test for stability. Also in such a system

$$G^*(j\omega) = \frac{1}{T}[G(j\omega) + G(j\omega - j\omega_s) + G(j\omega + j\omega_s) + \cdots + G(j\omega - nj\omega_s) + G(j\omega + nj\omega_s)] \tag{2}$$

Where T = sampling period in seconds
$\omega_s = 2T$
n = 0, 1, 2, 3, etc.

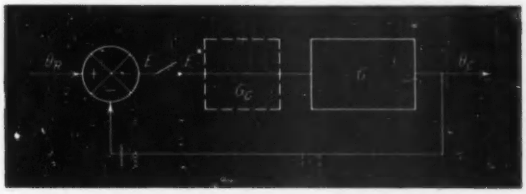


FIG. 1. Simple sampled data system.

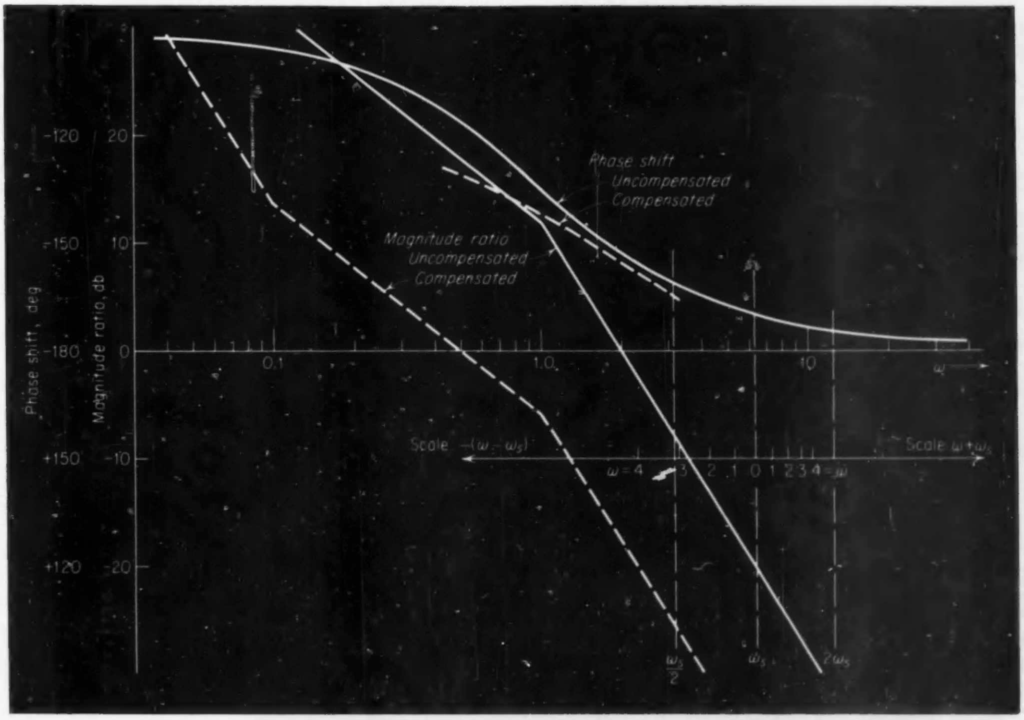


FIG. 2. Bode diagram evaluation of $G^*(j\omega)$ for $G(j\omega) = 4/j\omega(j\omega + 1)$, $T = 1.0$.

The series in Equation 2 usually converges rapidly enough so that only a few terms are required. The terms must then be evaluated, vector additions made at each frequency, and the results plotted. The problem is to determine how many terms are needed, to evaluate each term rapidly and accurately, and to design compensation where needed.

The Bode diagram may be used to solve all parts of the problem. First the normal Bode diagram is drawn, correcting only for the gain multiplier $1/T$. A simple illustration is shown on Figure 2 for the transfer function

$$G(j\omega) = \frac{4}{j\omega(j\omega + 1)} \tag{3}$$

with $T = 1$ for convenience. The frequencies $\omega_s/2$, ω_s, $2\omega_s$, etc. are marked. All terms in the series may be evaluated from this one plot. The term

$$G(j\omega) = \frac{4}{j\omega(j\omega + 1)}$$

can be evaluated directly. The second term

$$G(j\omega - j\omega_s) = \frac{4}{j(\omega - \omega_s)[j(\omega - \omega_s) + 1]}$$

$$= \frac{4}{-j(\omega_s - \omega)[1 - j(\omega_s - \omega)]} \tag{4}$$

is evaluated by adding a second abscissa scale for $-(\omega - \omega_s)$ as shown on Figure 2. This scale shows $\omega = 0$ where the original scale places $\omega = \omega_s$. For convenience the new scale is laid off directly in values of ω, increasing to the left of the ω_s location. The magnitudes are read directly from the plot with no correction. The angles are also read directly, but for the second term the conjugate of the angle must be used. In like manner the third term is

$$G(j\omega + j\omega_s) = \frac{4}{j(\omega + \omega_s)[j(\omega + \omega_s) + 1]} \tag{5}$$

which requires an additional scale laid off from the ω_s line, with increasing ω to the right as shown on Figure 2. Magnitudes and angles are read directly with no corrections. This procedure may be continued for as many terms as necessary. For terms of the type $G(j\omega - nj\omega_s)$ the conjugate of the angle must be used, but all else is read from the Bode diagram without change.

The number of terms required is determined by inspection. On Figure 2 it is apparent that the largest magnitude for the third term is -20 db, and all higher terms are even more negligible. Thus, for this illustration only two terms are needed. Similar reasoning applies to any problem. A polar plot for the system is shown in Figure 3.

To compensate the system to $M_p = 1.5$, draw the M-circle in Figure 3. Since phase lead compensation will not work, the problem reduces to the design of a phase lag compensator which attenuates the frequencies immediately below $\omega_s/2$ without permitting much phase shift in this range. A suitable set of asymptotes may then be added to the Bode diagram as shown in Figure 2. The resulting polar plot is shown in Figure 3.

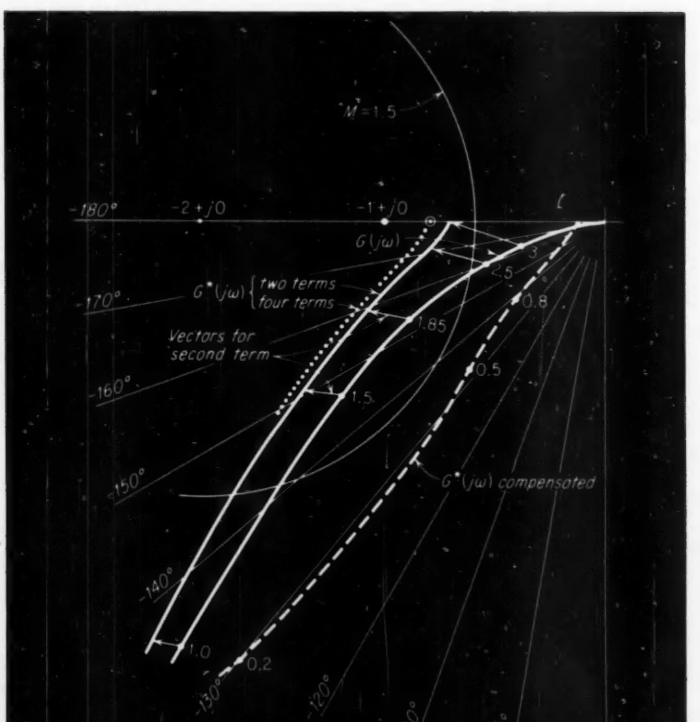
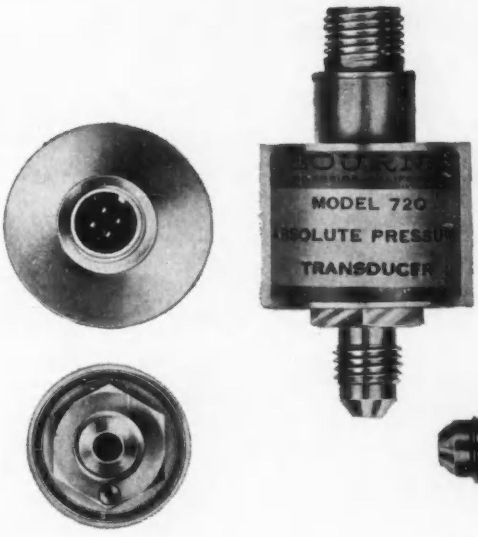
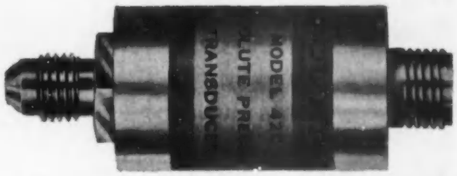


FIG. 3.
Polar plot of $G(j\omega)$ and $G^*(j\omega)$ as in Figure 2



UNITS SHOWN ACTUAL SIZE



Bourns Pressure Transducers

SUBMINIATURE SIZE

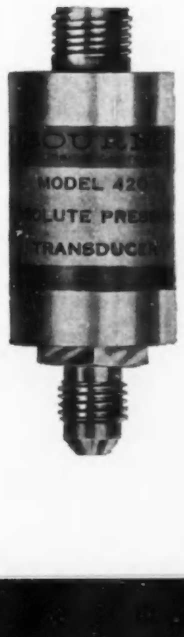
HIGH RELIABILITY

These rugged miniaturized instruments weigh less than 4 ounces. Nevertheless, each unit is built to the same uncompromising standards that have won a place in every major missile program for Bourns instruments. At ±35G vibration, these compact instruments deliver a high level, low error, noise-free signal. Available in absolute or gage pressure versions, over a wide pressure range, the 420 and 720 lines will meet your most exacting performance and reliability requirements. These units, with a wide selection of mountings, pressure fittings and electrical connections, illustrate Bourns' ability to translate the most stringent requirements into high-performance transducers you can depend upon. They prove the statement—*in pressure transducers . . . it's Bourns for leadership.*

Specifications

	Model 420	Model 720
Pressure ranges	0-15 to 0-350 psi	0-350 to 0-3500 psi
Operating temperature	−65 to +165°F	−65 to +165°F
Static error band	1.0 to 1.3%	1.0 to 1.3%
Dimensions	1.0" x 1.6"	1.31" x 1.25"
Weight	4 ounces	4 ounces

Write for complete technical data



BOURNS

Bourns, Inc., Instrument Division
6135 Magnolia Ave., Riverside, Calif.
Field Engineering Offices:
Huntington Station, L.I. and Dallas, Texas
Pioneers in potentiometer transducers for position, pressure and acceleration. Exclusive manufacturers of Trimpot®, Trimit®, E-Z-Trimit®.

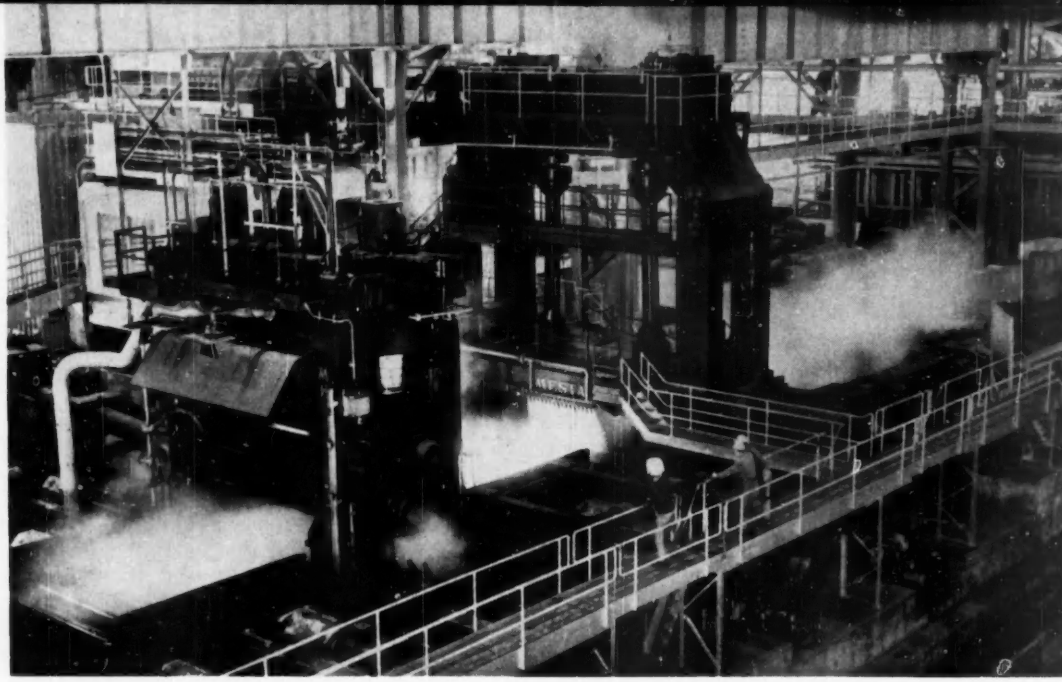


FIG. 1. Digitally controlled 140-in. hot plate mill.

Digital Computer Runs Hot Plate Mill

The new 140-in. four-high slabbing mill in the Lukens works at Coatesville, Pa., should interest any control engineer. A transistorized digital computer calculates screwdown settings from initial openings, limits, and draft information punched in by the operator. The whole rolling schedule is computer programmed, except for the turn-around after the intermediate limit. Preset programming wouldn't do for this primarily special order mill.

CLIFF BURDICK, Lukens Steel Co.

In the steel industry, plate rolling mills have generally been automated by preset programming systems using such devices as plugboards and patchcords or punched cards to store the sequential roll screwdown settings required to roll an ingot to a finished plate or slab. Such systems simplify the mill operator's job considerably and offer plenty of flexibility for the usual mill where plates are rolled to certain standard sizes, whether repetitively for stock or even occasionally. But the idea of permanently storing the program for producing a specific size of plate makes almost no sense for a special order shop like the Lukens hot plate mill. Here a piece will infrequently be reproduced.

The problem at Lukens therefore was how to simplify the operator's task on a special order mill and thereby improve mill efficiency. The practical answer, brought to its finally installed form by General Electric Co.'s Industry Control Dept. for the mill shown in Figure 1, is a special purpose transistorized digital computer that saves the operator from calculating many intermediate roll settings, applies the setting reference signals directly to the roll screwdown system, and automatically controls all the mill passes necessary to bring a piece to two separate thickness limits.

The process

A brief description of a typical plate rolling process will explain the mill operator's tasks and how the new computer helps to simplify them, see Figure 2. Hot ingots of steel direct from the soaking pits are first rolled lengthwise to a reduction on the order of 10 percent or greater of the thickness, then turned crosswise and rolled to a final width. This bidirectional rolling is done to produce the desired physical and metallurgical properties in the finished plate. The piece is started

The Rolling Process . . .

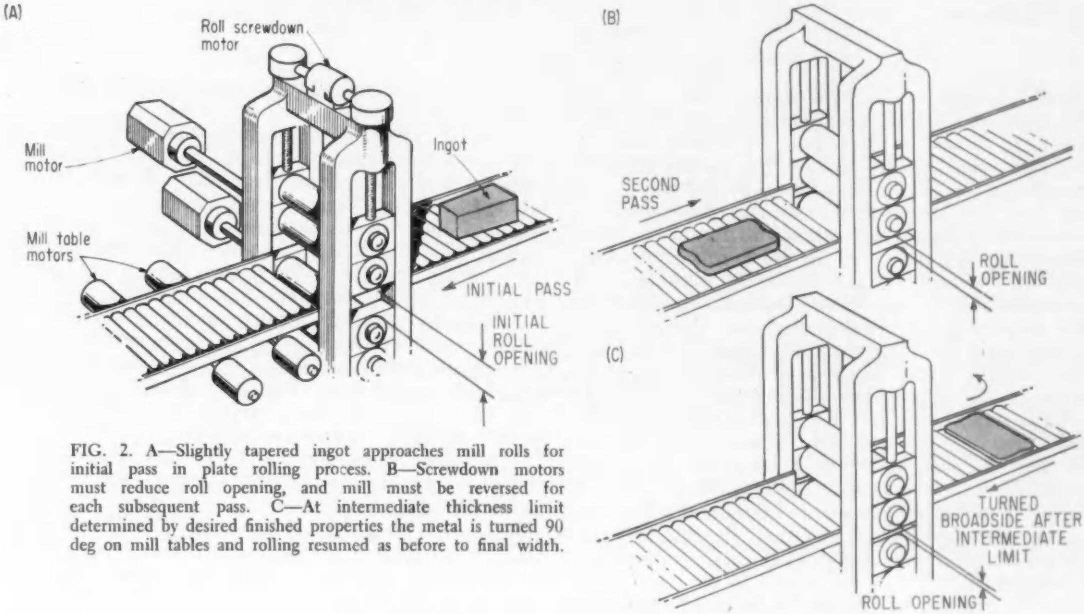


FIG. 2. A—Slightly tapered ingot approaches mill rolls for initial pass in plate rolling process. B—Screwdown motors must reduce roll opening, and mill must be reversed for each subsequent pass. C—At intermediate thickness limit determined by desired finished properties the metal is turned 90 deg on mill tables and rolling resumed as before to final width.

. . . And Its Control System

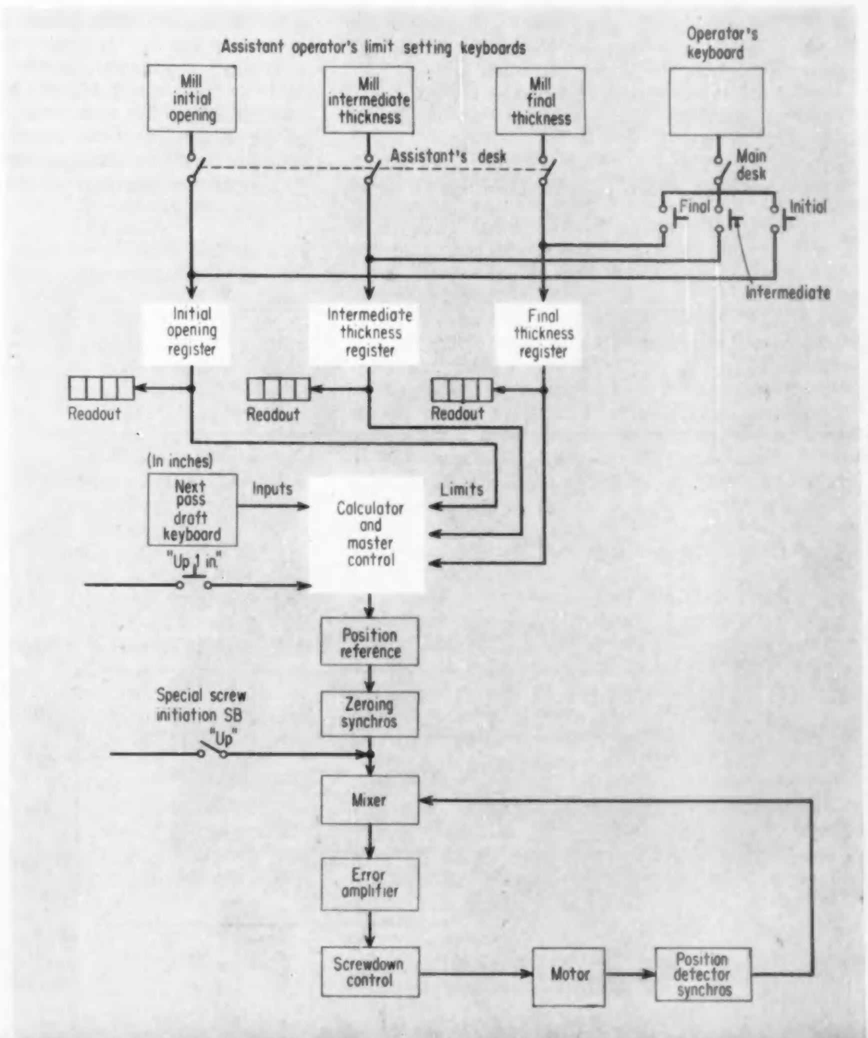


FIG. 3.
Automatic control system uses digital computer to relieve operator of roll opening calculations.

lengthwise with a very light initial draft to remove the taper due to the mold and break whatever scale may have formed on its surface. The initial roll setting thus must be calculated by the operator from the known size of the mold. The operator must then pass the piece backwards through the reversing mill at a somewhat heavier draft determined from experience, reverse the mill again for the third pass, and so on until he approaches the intermediate thickness limit predetermined for desired metallurgical properties. At this point he must calculate the exact change in roll setting required to produce the intermediate limit. The partially rolled piece must then be turned 90 deg and a similar procedure followed to the final width.

Thus, the operator of a reversing hot mill has to estimate successive roll openings. This requires some of his time and also distracts him from other important factors in the process that ought to be watched. A digital computer can make these calculations. The new Lukens computer does. It also starts the rolls and mill tables automatically in the right direction during each screwdown operation by an "almost in position" signal from the screwdown position detector. A load cell on the rolls senses when the metal leaves the rolls on the completion of each pass to stop the rolls and the mill tables and start the screwdown to the next draft position.

The computer and master control

A block diagram of the new control system shows the computer inputs and outputs, Figure 3. With this system the operator needs only to punch in

- initial roll opening, which depends on ingot size,
- the intermediate thickness limit, at which the metal is to be turned,
- the final limit, and
- the next draft, which is to be taken on all passes after the first pass, except when approaching the two limits.

The draft selected depends on the composition of the metal being rolled and on the properties desired in the finished plate. Drafts on this brand new 140-in. wide four-high mill greater than 2 in. will not be taken automatically unless the operator over-rides a safety check circuit by holding down a pushbutton marked "Speed Up Anytime", which also permits mill speed to go above base speed any time the mill is running.

All of the operator's instructions are entered into the control system as data for the computer and are stored in transistorized flip-flop registers until required for use in the calculations. The contents of these registers are continuously displayed by in-line digital readouts on the operator's control panel, Figure 4.

Operator's instructions are entered through keyboards containing four columns of ten pushbuttons each, with the columns left to right representing tens, units, tenths, and hundredths of inches. The pushbuttons on the keyboards are of the maintained contact type, interlocked so that only one button on any column can be depressed at one time. Lights in the button heads are wired to light only when a button is down in all four columns. The next draft keyboard has only three columns, and the units column has only the 0, 1, and 2 buttons wired in.

Four keyboards are provided—one for each of the operator inputs. The initial opening and two limit keyboards are the assistant operator's desk, and the next draft keyboard is on the right-hand side of the main operator's desk. A fifth keyboard is provided (on the left side of the main desk) so that the operator can at any time change the values set into the computer registers by the assistant operator.

Besides the contents of the operator's instruction

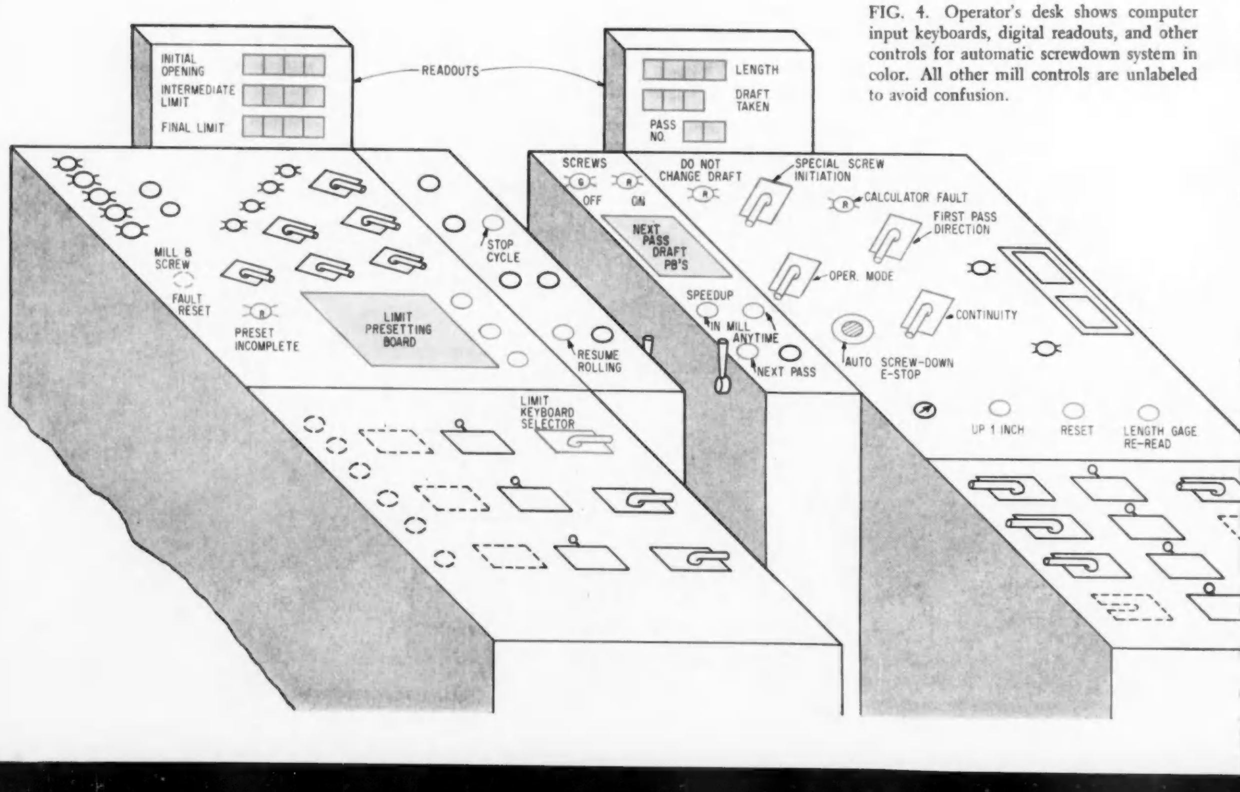


FIG. 4. Operator's desk shows computer input keyboards, digital readouts, and other controls for automatic screwdown system in color. All other mill controls are unlabeled to avoid confusion.

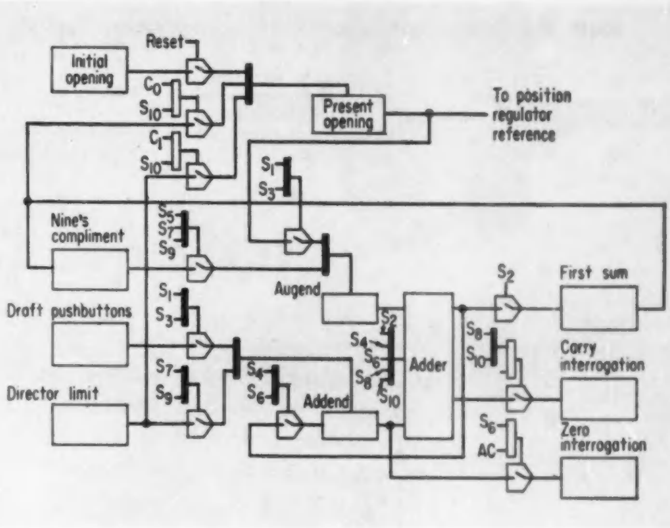


FIG. 5. This logic diagram of the digital calculator is used to explain its operation.

registers the computer also displays for the operator the draft actually taken on each pass as calculated from the change in screwdown settings, the number of passes since the start of the schedule and the length of the metal each time it leaves the mill on the operator's end (upper right side of operator's desk, Figure 4). The length gage is an infrared scanning device that is not part of the automatic control system proper and will be described in a separate article in a future issue.

Operation of the digital computer for automatic screwdown control can be understood from Figure 5, in which AND gates are represented by unfilled rectangles and associated switches that close only when all of the inputs to the rectangle are present simultaneously, and OR gates are represented by filled-in rectangles and associated switches that are closed whenever any one or more of the inputs to the rectangle are present. The inputs to the gates in Figure 5 are pulse outputs numbered in sequential order of a master sequencing shift register.

Automatic operation is started when the operator presses the "Screw Reset" button which causes the contents of the "Initial Opening" register to be placed in the "Preset Opening" register, the output of which is converted to an analog synchro signal and becomes the reference for the roll screwdown servosystem. After this intial setting, the computer calculates the new desired screw openings for each succeeding pass by subtracting the next draft from the present opening and comparing the result with the limits.

Sequence shift register pulse S_1 gates the present opening code into the augend register and the next draft code into the addend register (actually the nines' complement code is read into the addend register to effect subtraction, since binary-coded-decimal code is used); S_1 also presets the adder carry to one. S_2 causes addition by gating five clock pulses to the shift registers in the adder and also gates the sum to the first sum register. S_3 causes exactly the same events as S_1, and S_4 again causes addition but gates the new sum back into the addend register. Thus the new position calculation is made twice, successively, with the two results in the first sum and addend registers respectively.

Signal S_5 now gates the nines' complement of the first sum to the augend register while resetting the adder carry to one. S_6 adds, puts the result in the addend register, and interrogates it for zero. If all operations to this point have been made correctly, the last sum should be zero. If it is not zero, the master sequencing shift register is reset to S_1 and the calculations are repeated. If the calculation fails the second time, the computer is locked out and a fault indicator is lighted on the operator's right hand desk.

If the addition due to S_6 produces zero on either the first or second try, S_7 appears to gate the nines' complement of the first sum into the augend register and the director limit into the addend. The addition of these two values by S_8 should produce a carry of one if the limit opening is larger than new position opening in the first sum register. S_9 and S_{10} repeat the limit check caused by S_7 and S_8 and compare the carry due to S_{10} with the carry due to S_8. If these two are the same, a carry of one (C_1) sets the director limit value into the present opening register as the new screwdown reference, and a carry of zero (C_0) sets the value in the first sum register into the present opening register.

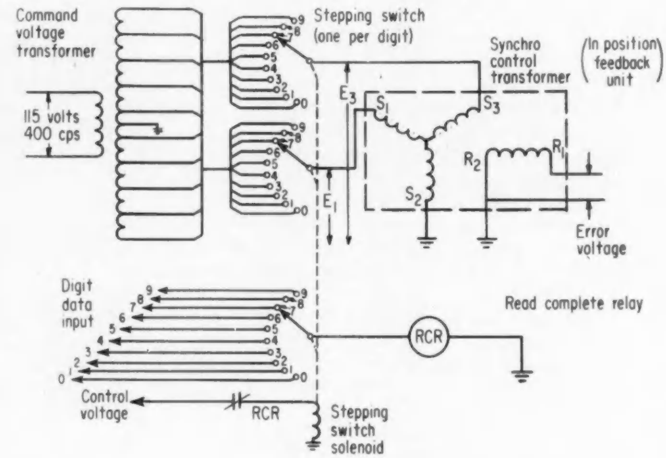
The master sequencing shift register is shifted from one position to the next by pulses from the computer clock (the primary pulse source, with a basic rate of 15 kcps) or from various points in the calculator. Therefore the timing between the pulses from the master sequencing shift register varies widely. Specifically, S_1, S_3, S_5, S_7, and S_9 have only to transfer numbers from one register to another, and one clock time is sufficient. On S_2, S_4, and S_6, the shift must be made after the addition is completed—on S_8 and S_{10}, after the checks are satisfied. The entire calculation takes 4 millisec maximum if it has to be repeated and only 2 millisec if it does not. These times are negligible compared to motor current time constants in the screwdown system, so the computer should not slow mill operation but rather speed it by eliminating operator calculations.

The automatic screwdown motor and position detector are mechanically aranged as shown in Figure 6. A three-speed synchro system is used as the roll position (opening) detector, with one revolution of the least significant synchro S_1 representing 1 in. Since the smallest incremental change in roll position that can be ordered by the operator on this mill is 0.01 in., the detector is arranged to have an accuracy at its shaft of ± 0.005 in. (The largest opening for the mill is 30 in.)

The new roll opening calculated by the digital computer and stored in the present opening register is converted to a synchro signal by the standard GE numerical position control system described in Reference 1. In short, each binary coded decimal digit is decoded to energize one of ten separate lines as in Figure 7. Magnetic static switches scan to the energized lines, at which time the correct taps on specially tapped transformers are connected to the synchro control transformer stators for each digit

Roll Opening Detector

FIG. 7. Proper taps on special transformer are selected by output of digital computer to simulate synchro signals for correct adjustment of roll position. Stepping switch shown has been replaced by static switching.



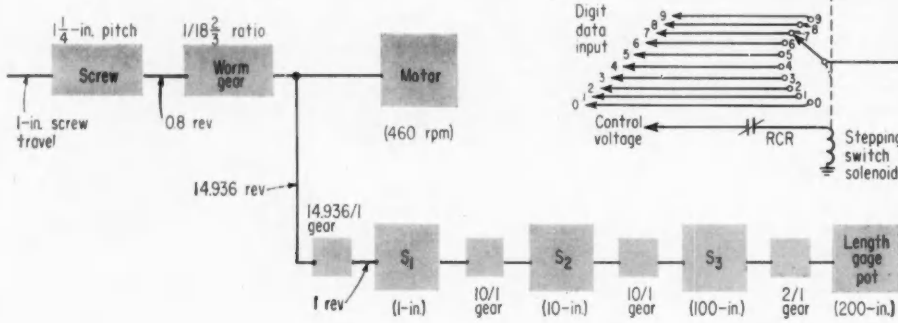


FIG. 6. Mechanical arrangement of motor and position feedback synchros in screwdown servosystem.

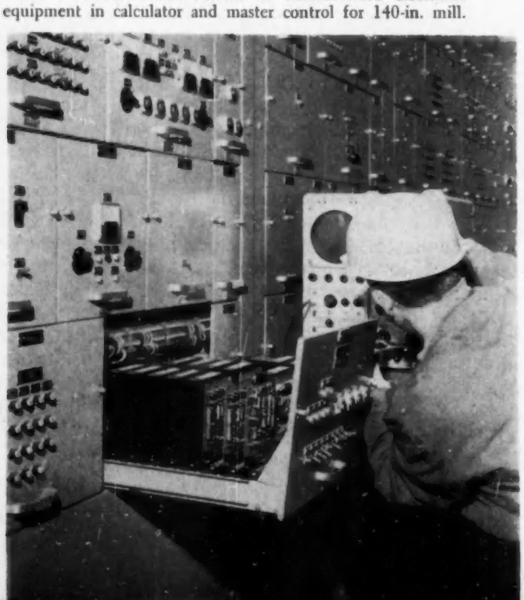
position. The four digit positions of the present opening register represent tens, units, tenths, and hundredths of an inch. The output of the tenths digit register represents tenths of a revolution of the S_1 synchro. For the hundredths position, a second tapped transformer for the S_1 synchro is connected to interpolate between the tenths taps of the first.

If the rotor of any of the three synchros is not at the commanded position, an error signal is generated. A thyrite varistor mixer-discriminator circuit (Reference 2) takes over from here to pass the control successively from the coarse to the finer speed synchros as the screwdown approaches the new opening commanded by the computer.

Construction and maintenance features

The digital computer and master control equipment are entirely transistorized, and wire-wrapped modular packages such as those in Figure 8 are used throughout. Each of the plug-in packages has grooved sides designed to facilitate measurement of its input and output signal and power connections while it is plugged in. Each of the plug-in connector pins is brought out to a test terminal at the bottom end of the nearest groove, and the other end of the groove at the top of the package is appropriately numbered. To check any voltage, a test instrument probe is merely touched to the correct pin number at the top of a groove, then slid down the groove until it contacts the test terminal.

FIG. 8. Modular construction of transistorized electronic equipment in calculator and master control for 140-in. mill.



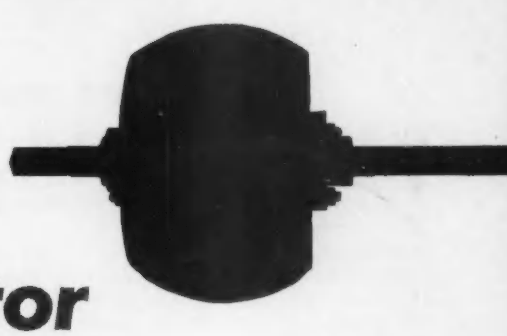
As mentioned before, the basic clock pulse rate for the digital computer is 15 kcps. Because a steel mill is a particularly adverse environment for transistorized electronic equipment, two other clock rates were provided to make maintenance easier. A higher one at 20 kcps was included as an aid in marginal checking of the transistor circuitry. High ambient temperatures and certain aging effects cause transistor characteristics that make high frequency gain deteriorate; thus raising the clock rate to 20 kcps as a test should show up transistors that may soon fail in service. Reversing this line of thinking led to the inclusion of a 10 kcps clock that would permit continued operation of the system in the event of sudden marginal-type failures that would prevent successful operation at the 15 kcps design rate. Both these ideas have proved invaluable.

Properly documented performance figures for the automatically controlled mill are not yet available. Due to the recent steel strike the mill has not been in full capacity service long enough to produce sufficient tonnage for this study. The new mill is fully accurate and fast enough to produce large finished plates directly. But all-in-all the experience gained so far with the new mill is not considered sufficient to make an accurate efficiency comparison with the same type of mill under straightforward manual operation. It suffices to say that the digital computer has performed satisfactorily during its limited operation.

REFERENCES

1. *GENERAL ELECTRIC COMPANY'S NUMERICALLY CONTROLLED POSITIONING SYSTEM*, J. D. Cooney and B. K. Ledgerwood, "Control Engineering", January 1958, pp. 92-94.
2. *VARISTOR STATIC SWITCHING NETWORKS FOR MULTISPEED SYNCHROS*, L. U. C. Kelling, "Control Engineering", February 1959, pp. 67-70.

The Strange New Ball Motor



Even this late in the history of electric machines, the search for an ideal *adjustable-speed ac drive* persists. The latest discovery is the spherical induction motor, which departs radically in form and principle from conventional squirrel cage types. Although yet unproven, it provides a unique base for further studies.

E. R. LAITHWAITE
Manchester Univ. (England)

Controlling the speed of a conventional squirrel cage induction motor is a difficult thing to do, involving either pole changing techniques or an adjustable-frequency power supply. And the frequency ranges attainable by such means are at best limited. The reasons that the induction motor is so poorly suited for adjustable speed operation become obvious with a consideration of some basic theories applicable to ac machines.

When polyphase excitation current is applied to the stator coils of a squirrel cage induction motor, it establishes a magnetic field that rotates around the stator at synchronous speed S. The latter is a function of line frequency f and the number of stator poles P:

$$S = \frac{120f}{P} \text{ (in rpm)}$$

As it cuts through the bars of the squirrel cage, the rotating field sets up currents in the rotor conductors. These currents cause a magnetic field that locks in with the rotating field and brings the rotor up to near synchronous speed. Shaft speed in rpm is given as:

$$N = \frac{120f}{P}(1 - s)$$

where s is the slip or speed difference between shaft and rotating field. To achieve good operating efficiency, the value of s must be a small decimal fraction and should not vary appreciably. Thus there are only two variables (f and P) that can be used as the basis for speed control in squirrel cage motors.

The above discussion applies to motors having conventional cylindrical rotors. It now appears possible to introduce a new control variable by the adoption of an unorthodox type of construction in which rotor and stator approach the shapes of concentric spheres. The third variable is the angle between the plane of the rotating field and the motor shaft. Normally the field plane is perpendicular to the shaft. In the spherical motor, however, the field angle can be adjusted with consequent effects on the magnitude of motor speed.

Figure 1 illustrates the operating principle of the spherical machine. The first sketch shows an elementary model of a conventional induction motor, consisting of flat disc, free to rotate about its axis, and a short, discontinuous block of field coils (*ABCD*). When a polyphase supply is impressed on the stator block, it establishes a traveling magnetic field that acts perpendicularly to the disc radius. The linear speed of the field is:

$$V_s = 2\,pf \text{ (in./sec)}$$

where p is the pole pitch expressed in inches. If the stator block dimensions *AB* and *CD* are small compared with the mean distance r of the block from the center, the disc accelerates to a rotational speed of

$$S = \frac{60\,V_s}{2\pi r} \text{ (rpm)} \qquad (1)$$

So far this is normal induction motor practice. Now assume that the axis of the stator block is skewed at angle θ from its original position. The speed of the traveling field is still V_s, but it locks in with the disc field at a new effective radius r′, which is equal to r cos θ. Thus from Equation 1, the new rotational speed of the disc becomes:

$$S_\theta = \frac{60\,V_s}{2\pi r \cos\theta} \text{ (rpm)} \qquad (2)$$

Equation 2 holds true even when it is assumed that the traveling field acts at the same mean radius r as originally. In this case, however, it must also be assumed that skewing the field block actually increases the *effective* speed of the traveling field. The simple model in Figure 2 justifies this statement. Here a traveling field, generated by alternate north and south poles, traverses groove *PQ* set at angle θ to the field motion. A steel ball rolls along the groove starting at point *P*. If the ball moves in synchronism with the field, it must traverse the distance *PQ* in the same length of time that the field is covering the shorter distance *PR*. Thus, ball velocity is necessarily higher than that of the field. If this analogy is extended to an induction motor, it must be inferred that angling the field increases motor rotational speed.

HOW ADJUSTABLE SPEED IS OBTAINED

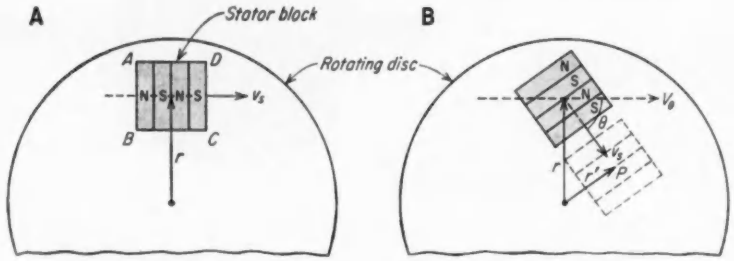


FIG. 1. Schematic of simple disc motor with short stator block.

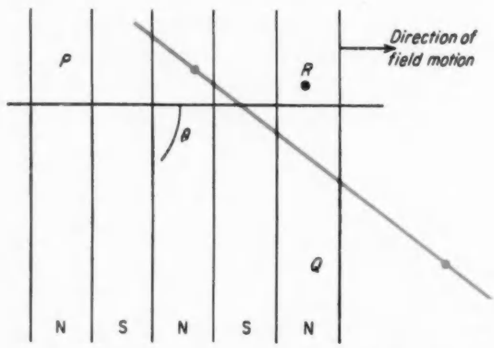


FIG. 2. Rolling ball analogy shows effect of skewing stator block.

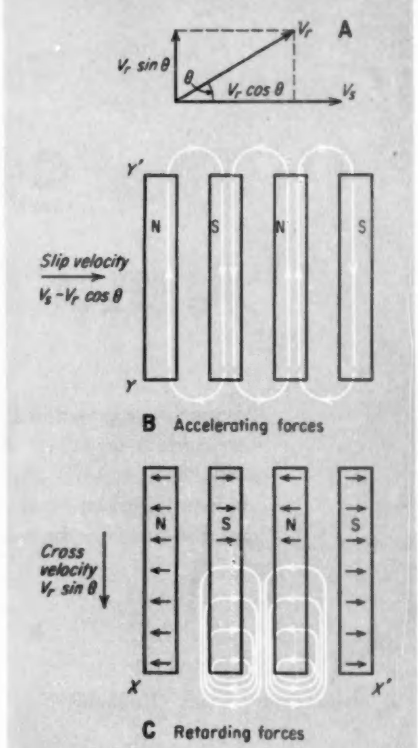


FIG. 3. Current and voltage loops established by two components of field velocity.

Movement of the rotor across the angled magnetic field resembles in some respects the sailing of a boat across the wind. Forward motion is possible only if the resistance to the sideways thrust is greater than that to the forward thrust component. In the yacht the keel offers this opposition. The approach taken to achieve similar resistance in the spherical motor can be seen in Figure 3A, which resolves rotor velocity vector V_r along and perpendicular to field velocity vector V_s. Figures 3B and 3C portray the resulting currents induced in the rotor disc. The slip velocity in the direction of the traveling field (Figure 3B) produces emfs along YY′ proportional to $(V_s - V_r \cos\theta)$ per unit length. Current caused by these emfs exerts accelerating forces on the rotor. The cross velocity normal to the field direction (Figure 3C) produces emfs along XX′ proportion to $V_r \sin\theta$ per unit length. Resulting currents exert retarding forces on the rotor.

There is one inherent factor that tends to keep motoring torque high while minimizing side thrust. This is the greater length of path (YY′) over which the accelerating voltages are induced. This makes for accelerating currents that are higher than those that retard. In addition, the resistance to the retarding currents can be increased by making the width of the poles large in comparison with the pole pitch. This reduces the induced cross velocity currents but has little effect on the beneficial currents due to slip velocity.

A favorable pole width/pole pitch ratio is actually a prime design requisite for angled field motors. In general, however, induction machines operate more efficiently with larger pole pitches. Thus the angled field construction is best suited for high power machines where the proper ratio can be met without resorting to very small pole pitches.

Practical requirements

While the disc-type rotor is quite suitable for demonstrating theory, practical machines using such rotors are out of the question. Unless the dimensions of the stator block were extremely small compared with the disc radius, various parts of the rotor would travel under the stator block at considerably different radial speeds. Hence, part of the stator block would act as an induction generator while the remainder provided motoring action. Poor efficiency and low power output would result. And any attempts to improve efficiency by reducing the stator block size would conflict with the requirements stated above for large pole pitches and a high pole-width/pole-pitch ratio.

Similarly ruled out is the technique of mounting the stator to act on the edge of the disc, which is then extended in thickness to produce the conventional cylindrical rotor. The reason for this is that the cylindrical stator cannot be mechanically oriented.

The only apparent practical arrangement is to form both rotor and stator as parts of concentric spheres. Figure 4 shows the schematic of an early machine with a four-block stator, in which it is possible to rotate

each block while maintaining a constant rotor/stator airgap. Simultaneous rotation of the blocks through a mechanical coupling provides speed adjustment.

Theoretical performance

In a normal squirrel cage induction machine, a wave of magnetic flux traveling around the airgap induces emf and current into the rotor bars so long as the rotor turns more slowly than the field. Because the amplitude of the flux wave is uniform everywhere around the stator, there are no abrupt transients and it matters little whether the stator coils are connected in series or parallel. But in an angled field motor, whether disc or spherical, the stator windings do not form a continuous belt around the rotor periphery. The stator is divided into blocks spaced sufficiently from one another to allow them to turn freely. Because of the discontinuous construction, conventional induction motor theory no longer applies, even though block angle θ is zero. As an example of the unique requirements of spherical motors, the stator coils must be connected in series, never in parallel, for reasons that will now be explained.

Consider the simplest case, when the rotor is moving at exactly the same speed (V_s) as the rotating field. If the stator coils were connected in parallel, there would exist a field that was substantially uniform over the face of the block. As each tooth of the rotor lamination entered the leading edge of the block it would experience a rapid flux change (from zero to some value), that would induce high voltages and currents in the short-circuited rotor bar. These currents, in turn, would establish a rotor field that opposed the stator field. To overcome this opposition and maintain its flux constant, the parallel-connected leading edge stator coil would draw an extreme surge from the line. Operation with parallel connections, then, would be accompanied by unfavorably high transients.

The series-connected short stator block, on the other hand, has the unbalanced flux distribution depicted in Figure 5. Again, as each tooth reaches the block, it undergoes a rapid rise of flux that establishes a field equal and opposite to that of the leading edge stator coil. Now, however, the current drawn by this coil is limited by the impedance of the other coils in series with it and cannot maintain flux at its quiescent value. Hence the field at the leading edge of the block is neutralized. At the exit end of the block, the opposite effect occurs as the rotor current reverses in an attempt to maintain its field. Figure 5 thus shows the crowding of flux at this edge.

The conditions described for the series-connected stator lead to a graduated flux distribution that increases from a minimum at the entry side to a maximum at the exit end. Despite the fact that the rotor is moving at zero slip, then, each tooth meets a steady rate of change of flux as it progresses across the block. This means that voltages and currents are induced even at synchronous speed, leading to a magnitude of no load copper losses that exceeds that of conventional squirrel cage motors. In addition, other losses occur outside the block as the transported magnetic energy is dissipated in the rotor copper.

Motor operation is much more difficult to analyze when slip occurs and rotor speed is no longer equal to field speed. Detailed transient theory developed for this condition has yielded some unusual results:

(1) The exit edge losses of a short stator motor produce back torques on the rotor that prevent the machine from reaching synchronous speed on no load. The greater the number of poles n on the block, the more nearly the no load speed of the rotor approaches field speed. This effect is negligible if n is greater than four.

(2) The entry edge produces additional losses, the magnitude of which varies with slip. These losses are zero at slip values of $1/(n + 1)$, $2/(n + 2)$, $3/(n + 3)$, etc. and are actually negative over certain ranges of slip. Exit edge losses are zero at slip values of $2/(n + 2)$, $4/(n + 4)$, etc. The maximum loss due to the entry edge transient that occurs at zero slip is always equal to the rotor copper loss produced by the magnetizing current. The maximum exit edge loss at zero slip, however, depends on the inductance of the rotor bars when they are outside the stator block.

(3) Using a low resistance rotor slows the rate of flux buildup. This is a disadvantage in the short stator-block motor which, at best, achieves only a low flux density, even at the exit edge. Short stator machines therefore require fairly high resistance rotors.

(4) In a short stator machine the effective number of poles per stator block is reduced as θ is increased. This is due to the limitation in pole width.

(5) With a slip of $1/(n + 1)$ a well designed machine has zero entry edge loss and only small exit losses.

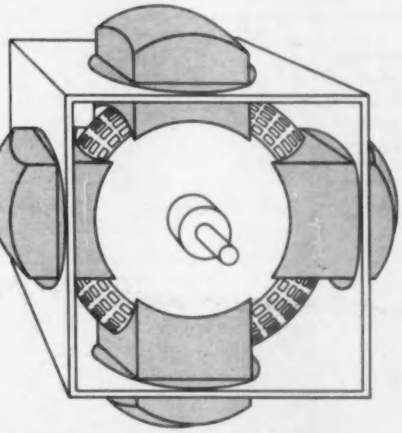


FIG. 4. Schematic of four-block spherical induction motor.

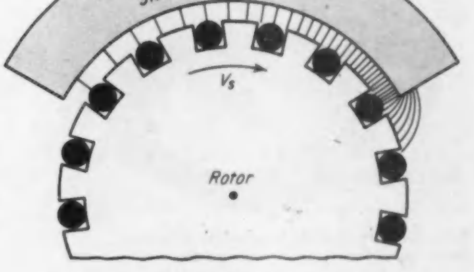


FIG. 5. Flux distribution in series-connected stator.

This value of slip is taken as the design condition for full load.

From a consideration of these points, certain further design criteria emerge:

▶ The rotor resistance must be matched to the proposed stator current density to give the rate of rise of flux required to best utilize the iron in the machine.

▶ For a rotor efficiency greater than 80 percent, n must be greater than four.

▶ Rotor construction must allow current to flow in any direction as demanded by each new position of the angled stator field. In effect, therefore, the rotor surface must be a conducting sheet.

Motor design

The early application of these design rules to the four-block construction resulted only in slow speed, low efficiency machines with a 2 to 1 speed range. Figure 6 shows such a machine with a 14-in. rotor diameter. Each stator block subtended 60 deg of rotor periphery, which yielded a pole pitch of only 1.8 in. in a four-pole block. Efficiencies were low (about 30 percent on 60 cycle supply) when the block was turned 60 deg to double speed, because this action halved the effective number of poles. Note that if the block is to be effectively four-pole at θ of 60 deg, it must be an eight-pole block to begin with.

To make the performance of angled field motor comparable to that of its conventional counterpart, the stator block construction must be altered to subtend a larger portion of the rotor periphery than the 60 deg mentioned. With a gain in block length, either pole pitch or the number of poles per block is increased. The two-block construction, Figure 7, used in later motors fulfills these requirements because it subtends about 140 deg of the rotor periphery. In addition to providing higher efficiencies, this design eliminates the out-of-balance magnetic pull between rotor and stator encountered with the four-block motor. Assuming no interaction between blocks, over 80 deg of periphery are available to dissipate the carry-over flux set up under each block.

Note that the slots visible in Figure 7 are not parallel to the axis of the stator housing, but are "preskewed". The latter technique provides a wider speed variation for a given angle of rotation. For example, a stator that is preskewed at 45 deg produces the same speed adjustment over ± 18 deg of stator rotation as the unskewed stator yields for a 0 to 60 deg rotation.

Comparison of Adjustable-Speed Drives (14/7 hp. at 750/375 rpm)

Machine Type	Efficiency, percent			Power factor			Power/weight ratio, hp/lb	Relative cost, percent
	High	Middle	Low	High	Middle	Low		
Schrage	79	78	67	0.99	0.77	0.65	0.0088	380
Ward Leonard	65	63	60	....	....	....	0.008	400
Ac commutator	76	78	77	0.9	0.75	0.65	0.0071	450
Spherical	61	68	75	0.84*	0.83*	0.81*	0.0105	260*
Squirrel cage 14 hp, 500 rpm (constant speed)	..	85	..	....	0.71	....	0.018	100

* Estimated on basis of prototype.

TWO TYPES OF MOTOR CONSTRUCTION

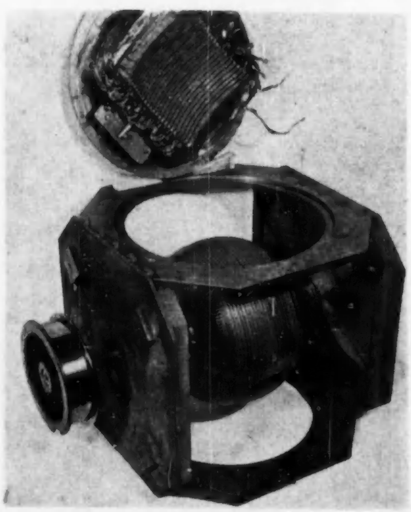


FIG. 6. Early four-block spherical induction motor. One block can be seen on top.

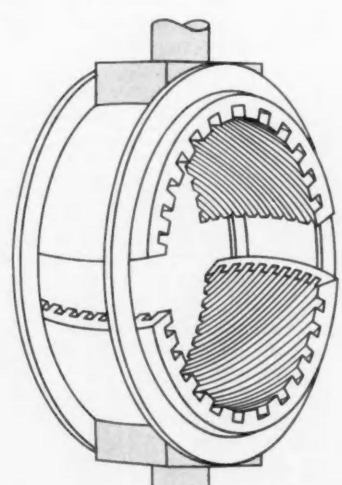


FIG. 7. Sketch shows skewed slots in two-block stator.

Motor construction

The rotor for a spherical induction motor is built up by stacking together several sizes of conventional motor laminations containing spaced slots. The laminations are stacked in small groups and then separated from each other by groups of smaller diameter slotless circular stampings. Conducting rings, such as those that are connected to the conventional squirrel cage rotor bars, are inserted into the slots formed between the two types of laminations. The required spherical form is approximated by a stepped arrangement of different diameter punchings. After assembly the interior of the rotor is cast full of aluminum and the outer surface machined to a true spherical shape on a turning machine or lathe.

The stator of the two-block machine is made without any inner surface machining. Differently shaped punchings cut from the same standard size blanks are stacked against a pair of forming rings so that the plane of the laminations is at right angles to the rotor motion. Wedges align the stampings in the radial plane. Offsetting the stampings from each other produces the skewed slots. The two blocks are skewed in opposite senses to prevent flux carry-over and allow the blocks to be rotated as a unit. The assembly is spot welded to retaining strips connected to the forming rings. This method of stacking the stator punchings grades the field speed to match the rotor surface velocities at different radii and thus reduces losses.

Performance characteristics

Figure 8 shows the results of a light load test at constant 50-cycle current on the two-block machine with 45-deg preskew. Figure 9 indicates the torque-speed curves at constant voltage for three different stator angle settings. Peak power was developed at a θ of 45 deg, at which setting all of the stator surface covered active rotor surface. Turning the stator surface off the rotor caused a loss in power; efficiencies fell from 73 percent at θ of 45 deg to 60 percent at 57 deg.

These tests showed that the machines have maximum speed when the rotor and stator blocks are in line. Thus if the maximum value of θ is limited to the angle of preskew, machine efficiency is not troubled by the sharp drop at top speed seen in Figure 9 for the 45-deg preskew machine. And the machine delivers peak output at top speed tending towards a constant torque characteristic.

Advantages and limitations

The main advantage of the spherical induction motor is continuous speed adjustment without the need for brushes, commutators, and slip rings. The brushless spherical motor is a simple mechanical structure requiring no auxiliary equipment whatsoever, in sharp contrast to most packaged drives where size, weight, and cost of the auxiliaries often exceed those of the motor itself. Starting involves only a simple across-the-line contactor with the machine in its low speed condition. Reliability should be as good as that of conventional squirrel cage types. With a small pilot motor to rotate the stator, the machine is readily adaptable to closed loop servo controls.

The accompanying table shows the relative merits of various types of adjustable-speed drives in terms of efficiency, power factor, power to weight ratio, and relative cost. Even in its prototype form, the spherical motor appears to have decided merits, especially as far as both cost and power to weight ratio are concerned.

The major limitation of spherical motors is that they are essentially multipolar. For speed ranges greater than 1.5 to 1, low-power machines (below 10 hp) have unavoidably small pole pitches; consequently, they yield low efficiencies and poor power factors. Above 200 hp, however, speed ranges of 2 to 1 with 80 percent efficiency are readily achieved. At still higher power levels, greater speed ranges can be achieved with efficiencies comparable to those of fixed-speed machines. Because of their relatively higher slip, the rotor copper loss of spherical motors is higher than their conventional counterparts. And due to the multipolar construction, top speeds are limited to 600 rpm.

The first 200-hp commercial machine using mechanical stator shifting is now under construction at Metropolitan-Vickers. In addition, there are designs underway wherein the effective angle of the field is changed *electrically*—by feeding a portion of the stator power through a pair of phase shifting regulators. This eliminates the physical movement between the rotor and stator, and the motor construction reverts to the cylindrical form of the conventional machine. Initial experiments indicate that besides simpler construction, this new approach will provide running speeds twice those of the original spherical motors.

MOTOR PERFORMANCE

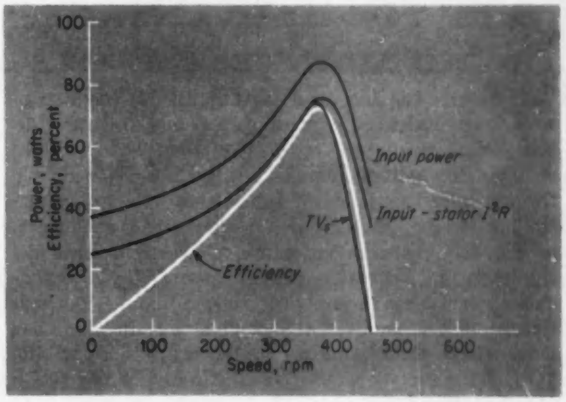


FIG. 8. Load and efficiency curves for two-block machine.

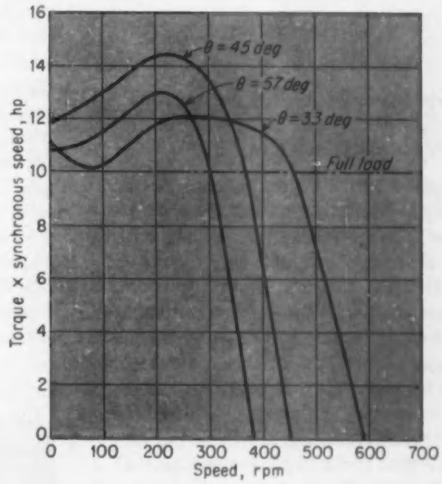


FIG. 9. Curves show torque-speed characteristics of same motor for three different stator settings.

(Advertisement)

JOURNAL OF APPLIED CONTROL DEVICES THAT NEVER WEAR OUT

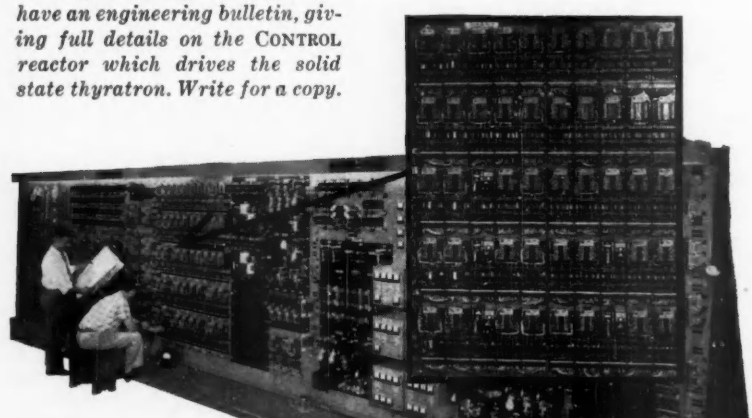
For Control Engineers Who Are Wearing Out Before Their Time

THEY TOOK ADVANTAGE OF (NO MAINTENANCE) STATIC CONTROL

Cutler-Hammer, Inc. and Arthur G. McKee & Co., American experts at control system and steel mill design, respectively, have just paid due respect to the problem of servicing complex automatic equipment in a foreign land thousands of miles away. They have installed CONTROL Switching Reactors and Transductors in the blast furnace automatic charging control designed for an Argentine steel company. Why? Because under normal operation, CONTROL Switching Reactors simply don't wear out! Yet look what they do: (1) They sequentially count charges and other functions and register this information on the operator's control panel; (2) through logic switching, they control and interlock the static skip hoist drive, the blast furnace large and small bell actuators, the automatic coke charging system, and the alarm system . . . tying them all into the operational cycle of the blast furnace. *This is static control, so named because Switching Reactors have no moving parts. Totally enclosed, these high permeability magnetic devices operate in the gritty, corrosive atmosphere of the steel mill with never a shutdown for maintenance. Want details? Write us.*

THREE LITTLE WORDS–*logic, switch, operate*

If you want some insight into Cutler-Hammer's insight, there are three words (above) to pay special attention to. *Logic:* CONTROL's Switching Reactors are designed to take a variety of input signals to be fed into several isolated control windings and thus provide AND, OR, NOT, MEMORY and TIME DELAY sequences. *Switch:* Orthonol® cores provide stiff snap action going from "off" to "on" states. The power switching ratio is 2500:1, even under 10% over-voltage conditions. *Operate:* There's no need for auxiliary hardware. CONTROL reactors directly operate such loads as solenoids, motor contactors and magnetic clutches. They're ideal for the solid state thyratron. They handle single loads up to 300VA. *We have an engineering bulletin, giving full details on the CONTROL reactor which drives the solid state thyratron. Write for a copy.*



CONTROL Switching Reactors in Cutler-Hammer system

STATIC CONTROL:

simple and standard

From where do your signal pulses come? Limit switches? Push buttons? Relays? Any transducer with an electrical output? The CONTROL Switching Reactor compiles them, remembers them, and then acts (logically) when the right one comes along. It's a selective device, for by presetting it, you will insure its operating only upon the proper combination of signals. The result? A CONTROL Switching Reactor will replace a relay system, and once replaced, you minimize maintenance and other old-fashioned worries. *And there's a size for every need up to 300VA output. There are CONTROL reactors which operate from standard line voltages, others which deliver standard load voltages, and now there's one which takes 120 volts in and gives 120 volts out! Full details? Your copy of our catalog awaits your request.*

Reliability begins with CONTROL

A DIVISION OF MAGNETICS, INC

DEPT. CE-77 BUTLER, PENNSYLVANIA

Installing Pneumatic Signal Transmission Systems

AMERICAN
PETROLEUM INSTITUTE
Committee on Refinery Equipment
Subcommittee on Instruments*

Pneumatic instruments are the most widely used control devices in processing plants despite the recent challenge from electronic control systems. Properly installed pneumatic signal-transmission links therefore remain an important aspect of successful operation of many new and modernized plants. However, even when a user elects pneumatic instruments for his plant, he still has a wide choice of tubing materials, configurations, and fittings and of supporting, protecting, and routing methods. The following information, based on agreement of instrument engineers from many petroleum companies, is a guide for choosing and installing the best pneumatic link.

As processing plants grow larger and more complex, correct installation of measurement and control signal transmission systems becomes increasingly important. Without reliable signals, personnel safety, plant performance, and duration of processing runs may be jeopardized during normal and emergency operation. Careful design, equipment selection, and construction assures satisfactory transmission systems at acceptable costs. Consideration must be given to:

- protecting signal leads to reduce possibility of damage by fire or mechanical shock
- excluding hazardous or noxious fluids from control rooms
- installing reliable air supplies
- providing facilities for manual control, for testing, and for ready access to instruments.

Industry practice has been to abide by one of the two principal transmission system pressure ranges recognized by ISA (Instrument Society of America) and SAMA (Scientific Apparatus Makers Association). These are 3-to-15 psig and 3-to-27 psig. Refiners usually arrange, particularly on new installations, to supply air at 20 psig for instruments in the 3-to-15 psig transmitted air range. However, 35 psig air pressure is used with springless, diaphragm-type operators which stroke single-seated valves, and 50 or 100 psig air pressure is frequently used for actuating piston operators furnished with large valves and dampers. To insure operation in emergencies, one refiner specifies that large actuators shall develop design thrust at 80 percent of nominal supply pressure and be mechanically capable of continued operation without damage at 120 percent nominal.

What's available in pneumatic tubing

Pneumatic transmission lines are usually ¼-in., or ⅜-in. OD. The ¼-in. size is preferred where it meets instrument manufacturer's requirements. Tubing is supplied in copper, aluminum, and plastic, either in single strands or in bundles.

Copper tubing—is more widely used than either aluminum or plastic tubing. It is supplied annealed or half hard.

Aluminum tubing—is currently becoming more common because of price advantage. In locations where atmospheric conditions induce sulfur attack, aluminum has shown better corrosion resistance than copper. However, aluminum tubing has not worked well in seacoast locations or in some petrochemical plants. Also, aluminum seems to be somewhat less resistant to vibration than copper. Care must be taken when installing aluminum tubing to provide sufficient electrical insulation (usually paint) between the tubing and other metals to prevent electrolytic corrosion. Currents caused by arc welding in the vicinity of the tubing may leave small pin holes. Spray and rebound from Guniting (sprayed concrete) has also been found to leave small pits in the tubing surface; therefore in areas where considerable Guniting is expected, some permanent form of protection like plastic jacketing is recommended.

Plastic tubing—is also currently becoming more

common. Such tubing is light, corrosion resistant, and has sufficient resilience to prevent damage on occasional freezeup. Plastic tubing is relatively inexpensive. Care must be used in selection of fittings since there is some tendency for plastic tubing to cold flow and develop joint leaks. Furthermore, some plastics burn, and most plastics lose strength above 200 deg F. The use of plastic tubing in outdoor processing areas is limited because of possible overheating and fire damage unless protected.

Both compression-bite type and flare-type tubing fittings are used, but of late the compression type is becoming more popular. Where plastic tubing is used because of atmospheric conditions it is good practice to apply colored (acrylic) plastic coating to the fittings, making coating damage more visible. Brass fittings are used with copper tubing, and anodized aluminum fittings (anodizing prevents mechanical seizure between tube and fitting) are used with aluminum tubing.

Tubing support and protection

The problem of supporting small lines and protecting them against mechanical and overheating damage is difficult and costly to solve. There is no agreement as to the best method of tubing installation, and no one method is likely to be always best.

Rack systems—have the advantages that individual tubes can be easily traced, repaired, or replaced, since many single tubes are separated on a rack. They have the disadvantage of highest installed cost since they must be assembled by field labor. Rack systems provide the least protection against mechanical damage to tubes. Some contractors, to reduce engineering and field costs, prefabricate support bars and assemble sections of vertical racks on the ground before erection. Figure 1 shows several ways of installing groups of single tubes on racks.

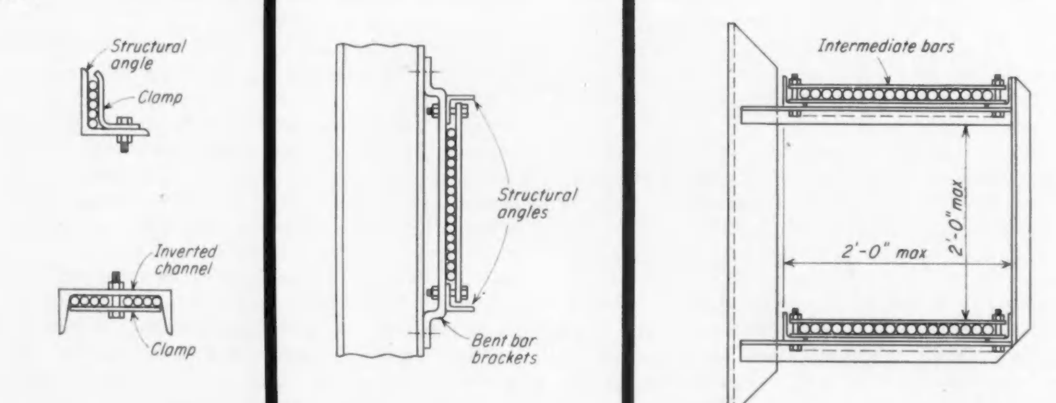
Trough systems—support groups of single tubes in much the same manner as rack systems, except the trough itself is a prefabricated length of perforated metal channel. Trough systems may be purchased and are often less expensive than rack systems from a materials and installation point of view, but they require more engineering effort.

Pipe systems—A number of tubes may be pulled through a pipe, resulting in a very well protected installation. The pipes are then supported and run in a manner similar to normal electrical conduit installations. Tubes are connected together in regular splicing fittings, junction boxes, or on bulkhead bars, depending on the amount of protection needed. Pipe should be galvanized inside if aluminum tubing is used. The table lists the number of tubes that can be loaded into various size pipes.

Bundled tubing—is offered by several manufacturers in a number of materials and with different protective coatings. Copper and aluminum tubing is sometimes spirally wrapped in layers, one tube in each layer being color coded for identification. The tube nests are covered with either a plastic-impregnated cloth-tape wrapping or an extruded plastic coating. Bundled tubing can be obtained with interlocking galvanized steel, aluminum, or other metallic

Suggested Rack Systems For Supporting Single Tube Pneumatic Transmission Lines

FIG. 1



For one or more lines with short spans. Suitable for indoor or outdoor installations.

For many lines. Only one bank of lines permitted. Suitable for indoors and outdoors, including tunnels.

Two-tier raceway with lines supported by intermediate bars. For sheltered locations.

SUGGESTED TUBE LOADING FOR VARIOUS PIPE SIZES.

	Pipe or duct size, in					
	¾	1	1½	2	3	4
¼-in. OD tubing	2	4	8	16	32	60
⅜-in. OD tubing	1	2	4	8	16	30

armor, giving protection for direct burial.

Bundled plastic tubing is also available with extruded plastic sheath or metallic armor sheath at relatively low cost. Where fire damage is a consideration, the tube bundle may be insulated with an asbestos jacket over the extruded sheath. Bundled plastic tubing covered with plastic protective jacket can be used underground and in conduit.

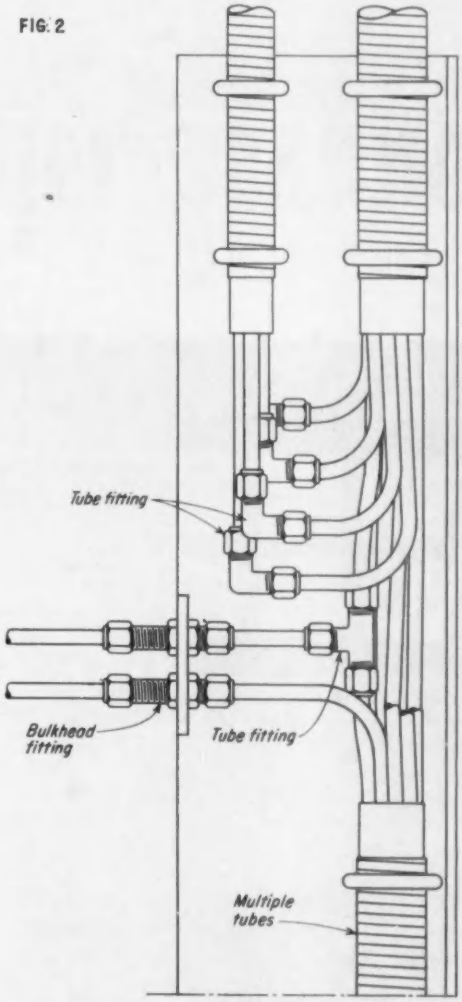
Field installation of bundled tubing can be simple, provided thorough engineering, including selection of cable termination points, is done in advance. Copper and aluminum tube bundles have high tensile strength and may be bent in short radii. Interlocking armor imparts great crushing resistance to the bundles. Bundles may be supported in expanded metal troughs, on steel messenger cable similar to telephone cable, or by suspension from pipe stanchions. Bundles may also be clamped to building walls or structural members with pipe clamps or special fasteners. Figure 2 details several ways of breaking out and connecting leads in armored multiple-tube bundles.

Several disadvantages exist with pipe and bundled-tube installations. Individual tubes are difficult to trace, and therefore their ends must be identified and permanently tagged prior to installation. Consideration must be given to the number of spare tubes to be installed initially. In pipe and bundled tube systems it is good practice to provide at least 10 percent spare tubes and spare rack space for about 25 percent more tubes. Filtered, dry instrument air is essential as it is difficult to clear a blocked tube in a pipe or bundle. The tubing system must be laid out carefully with all requirements stated in advance. In particular, the precise length of bundled tubing must be known before ordering.

Locating and routing tubing runs

Underground runs of pneumatic signal leads may often be shorter and better protected against fire and mechanical damage than overhead runs. However, underground ducts must be protected from accidental digging up and crushing by heavy equipment passing over them. This protection is frequently accomplished by embedding the ducts in a concrete envelope. Where ducts pass under roadways, the road may already provide suitable reinforcement. Parkway-type installations are often protected by a separate concrete slab. Underground ducts should be avoided where flooding with hydrocarbons or corrosive liquids is probable. Special attention should be given to location of tubing pull points in underground duct systems; otherwise replacing damaged tubes may be difficult and extremely costly. When underground routing is expected, the instrument program should be firmed up early in the project to avoid costly changes or additions.

FIG. 2

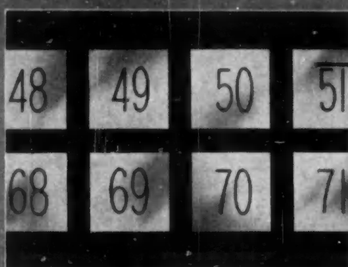


Details of breaking out and connecting tubes in pneumatic transmission multiple tube armored bundles.

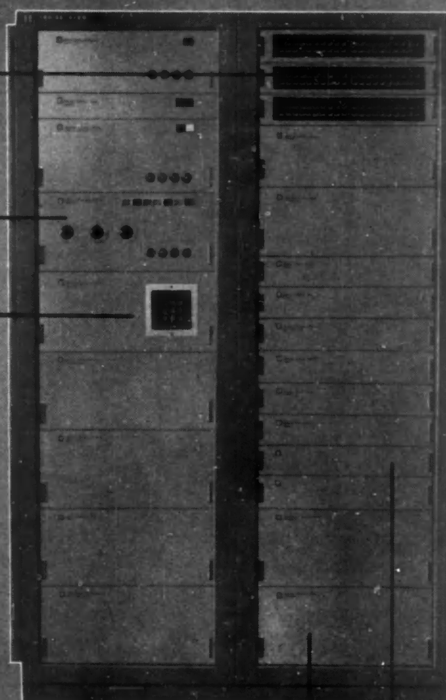
Overhead tubing runs, too, must be routed to reduce accidental mechanical abuse and possible damage to tubing from fire or overheating. They should not be located close to hot processing equipment or piping. Routing overhead runs along pipe racks may simplify support problems.

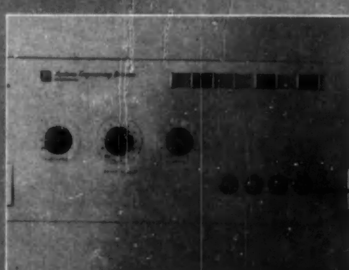
* This article is based on a portion of Section 7, Transmission Systems, of the API's forthcoming "Manual of Recommended Practices for Installing Instruments in Refineries". Publication is planned for early 1960. Copies will be available from the American Petroleum Institute Order Dept., 111 West 50th St., New York 20, N. Y.

New packaged

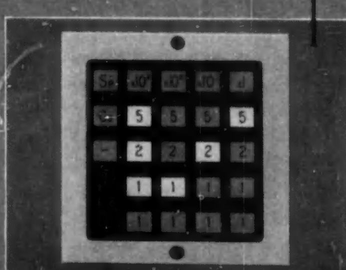


THREE 40-POINT ANNUNCIATORS make it easy for the operator to tell at a glance which variables are off-normal.

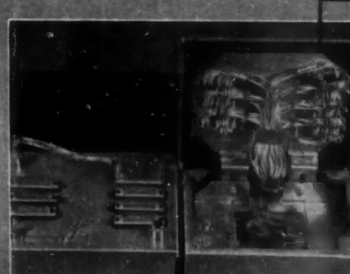




DIGITAL VISUAL DISPLAY and variable selector switches make it easy to select any single variable and watch all trends and changes continuously.



SERVICING IS SIMPLIFIED by an indicator-light panel showing the completion of each step in the analog to digital conversion. The sequence programmer can be changed from automatic to hand advance to permit operator to check each step.



UNIQUE INPUT SELECTOR is unusually dependable because of its sealed, oil-immersed construction. Servicing is normally limited to visual inspection every 6 months. Drawers pull out so voltage checks can be performed without shutting down system.

PINBOARD PROGRAMMING adds flexibility. You can change the logging or scanning sequence at will . . . substitute one type of input for another. Range, span, and zero adjustment are set by inserting pins in their proper places. No calculations are required. The pinboards are pinned in familiar units of measurements.

Honeywell logger-scanner

...accurate within ± 0.1% of reading

...pinboard programming for maximum flexibility

Here's a standard, all-purpose 120-point logger-scanner system with features formerly found only in more expensive, custom-designed equipment... the first of several packaged logger-scanners being introduced by Honeywell. It offers the ultimate in accuracy, flexibility, dependability and simplicity of maintenance. Wide ambient temperature operating limits—60 to 120°F—eliminate the need for special air conditioning equipment.

The Series 3120 accepts signals from primary measuring instruments—thermocouples, flow, pressure or other transducers. It measures these signals, digitizes them, and prints their values in immediately usable form. A thermocouple reference oven can be supplied to accommodate three types of thermocouple inputs—types T, J, and K—which are automatically linearized over their entire range to within 0.1% accuracy.

The operator can select either automatically or manually initiated logging cycles. He can set the system to log all variables automatically at preset intervals, or manually energize the system to operate on demand, between logging cycles.

Between logging cycles, the system can scan off-normal alarm points—high, low or both—at a rate of 7 points per second. Upon detecting an off-normal point, the system sounds an alarm, lights a point-identification light, and prints the time, point number and off-normal value on adding machine tape. During log cycles, off-normal points are printed in red on the log sheet.

Get complete details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone. MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

75th YEAR PIONEERING THE FUTURE

Honeywell

H HONEYWELL *First in Control* SINCE 1885

TWO TYPEWRITERS permit a single line log allowing columnar comparisons. Separate alarm printer records all off-normal variables.

STANDARD MODULAR COMPONENTS are assembled on chassis mounted as individual drawers in relay racks. All drawers are connected by plugs for easy servicing.

CIRCLE 141 ON READER SERVICE CARD

Key to Machine Tool Compatibility:

Data Processing for Numerical Positioning Systems

ROBERT A. BENNETT, The Martin Co. (Denver)

Although the general purpose digital computer is universally used for generating *continuous-path* numerical control data, it is almost totally overlooked in connection with *point-to-point* systems. For example, only one of the 31 numerically controlled positioning systems described by Cooney and Ledgerwood (Ref. 1) incorporates a computer for determining the optimum sequence of drilling or punching holes. The IBM-Fosdick block diagram includes an optional computer for stacking the punched cards in the proper order for attaining the most efficient combination of tool changes and table movements for boring a pattern of mixed-size holes.

Despite this current neglect, there are gains to be made by the application of computers to the point-to-point positioning problem. The first benefit is the optimization of the work program, which is the primary objective in the IBM-Fosdick example. A less obvious but much more important advantage is the standardization of the input procedure. One computer can be programmed to handle many kinds of systems, each of which would ordinarily require a special piece of data preparation equipment.

Statement of problem

In numerical positioning systems the control tape or cards contain codes that direct the machine to move the work (relatively) under the punch or drill. The codes must appear in a sequence that agrees with the tool sizes or tool changes. The coded tape or card commands also include certain intermittent functions such as "clamp", "punch", or "drill". The part definition data originates on the design blueprint, progresses to a program sheet, and then is transferred to the punched tape or cards by manually operated punching devices. The mathematics involved in the data preparation are simple addition and subtraction.

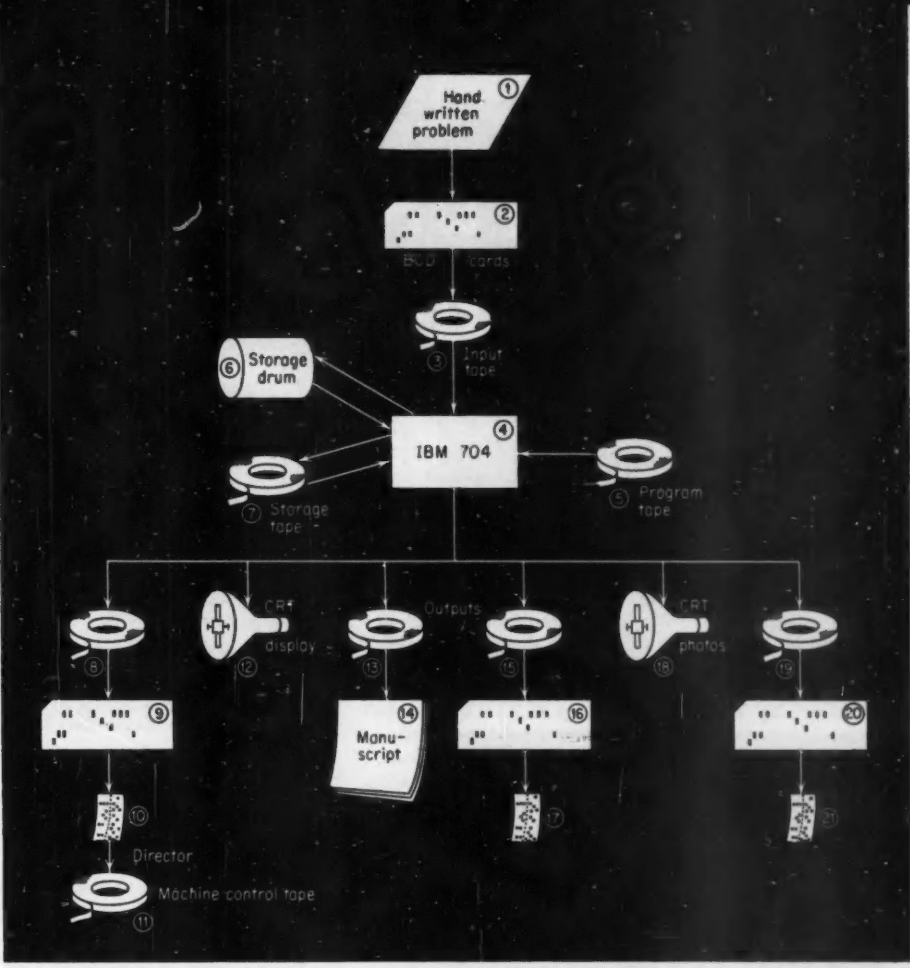
While data preparation for a single type of machine is reasonably straightforward, the process becomes much more complicated where there are several different ones. Progress toward standardization is slow; so at the present state of the art, a group of five machines, each from a different tool builder, may involve five distinct types of input media, data preparation equipment, numerical codes, and formats.

This situation obviously creates difficulties in the training of operating personnel in the various languages and methods of operation. Therefore, any company already enjoying the benefits of a general purpose digital computer and its peripheral data processing equipment should definitely consider taking advantage of this available capability before acquiring any complete systems, whether contouring or positioning. It is possible, for example, to develop a computer program capable of preparing tapes for any numerically controlled drilling machine using an eight-level punched tape. The difference in codes required by any particular system is resolved within the computer. Suitable tape punches are available that can copy the hole/no-hole combinations line for line as they appear in the cards coming from the computer or off-line punch. It is necessary, however, to provide the proper computer output routine so that the holes are correctly placed in the cards. The tape punching machinery copies the cards as though they were laid end to end.

System description

The generalized computer program block diagram illustrates how the computer is fitted into the positioning application. Numerous output routines are provided for preparing data for different systems and for different purposes. The tape preparation process begins with writing the hole positions in the prescribed language. The input listing is transcribed directly to binary coded decimal punched cards, which are verified in the manual keypunched operation, Block 2. The card data is transferred to magnetic tape for input to the computer by means of off-line equipment, Block 3. Block 4 represents the computer, and Block 5 contains the program tape or cards. Blocks 6 and 7 represent drums or tapes needed in the program for intermediate storage of information for later processing. An output routine generates and records on magnetic tape the complete data necessary to the operation of a particular machine. Off-line equipment transcribes the output tape first to punched cards and then to punched tape. The punched tape is read by a director, which produces the actual machine control tape, Block 11.

The example described thus far is a complete and workable system, typical of many already in use. With some language changes and corresponding program changes, hole drilling problems can be solved and the tape requirements for auxiliary machine control satisfied. Language alterations provide for stating the hole drilling problem, including additional intermittent functions peculiar to the machine. The computer operation then follows only those internal routines necessary for solving the added problem. In the hole drilling case this would surely include a mathematical determination



How the general purpose digital computer prepares control data for point-to-point positioning systems.

of the optimum sequence, which could be biased in favor of either fastest possible operation or least wear on the machine tool. (High speed drilling of mixed diameters causes excessive wear of tool holder turrets.) These new output routines permit the computer to generate data and print it on magnetic tape, Block 19. Off-line equipment transcribes the data to punched cards, Block 20; other equipment reads the cards and produces the machine control punched tape at Block 21.

The diagram illustrates other output routines that serve varied purposes. A printed manuscript containing understandable machine program data is printed on tape, Block 13, and cathode ray tube photographs (Block 18) are provided for checking during the computer run (Ref. 2). When checking hole drilling or punching data, the CRT routine indicates hole sizes and locations by printing coded characters such as dots, circles, and "X's" on the tube face or photograph. Blocks 15, 16, and 17 are included to indicate that additional output routines can be provided for other contouring or positioning machining systems.

Among the advantages of the computer approach to programming positioning systems are:

1. The input or planning language for numerical control problem statement can be standardized within a company, yet may be used for setting up problems for many different machine systems.
2. The problem statement language has been prepared in such a manner that the planner is required to do little or no mathematical computation.
3. Much diverse data preparation equipment is eliminated.
4. Programming personnel need not learn the many and varied languages required for the added machines.
5. After the problem statement, the only manual task in the system is the key punch and verifying function.
6. Optimum sequence of operations is provided for hole drilling, hole punching, and other positioning operations.
7. Data processing problems are restricted to the department best equipped to solve them.
8. The overall capability and versatility of the numerical control system are greatly enhanced.

REFERENCES

1. *POINT TO POINT POSITIONING SYSTEMS* I, II, and III, John D. Cooney and Byron K. Ledgerwood, "Control Engineering", January, February, and March 1958.
2. *VISUAL CHECK FOR TAPED MACHINE PROGRAMS*, Robert A. Bennett, "Control Engineering", August 1958.
3. *AUTOMATIC PROGRAMMING OF NUMERICALLY CONTROLLED MACHINE TOOLS*, Arnold Siegal, "Control Engineering", October 1956.
4. *APPLYING THE IBM 704 TO MILLING MACHINE PROGRAMMING*, Joseph Albert, Nils-Olof Olesten, and George Cain, "Control Engineering", June 1958.

Skewed-Axis Gears for Low Backlash

For high-ratio

right angle drives . . .

this new gearform ➔

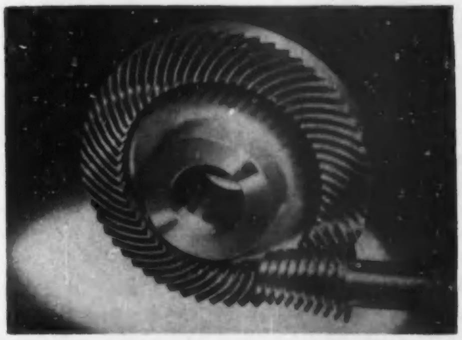


FIG. 1

joins

this old standby ➔

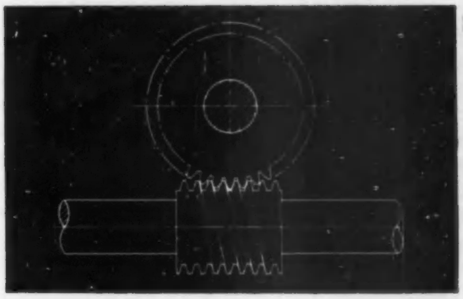


FIG. 2

WILLARD C. MACFARLAND
Spiroid Div., Illinois Tool Works

A common way of classifying gearsets is according to the spatial relationship of the axes of the individual gears in the set. Thus, there are the following broad groups: parallel axis (spur and helical), crossed axis (bevel), and skewed axis (wormgears). Each type has its own particular field of application, which is determined partially by the reduction ratio required, the space available, and the relative positions of input and output shafts. The wormgear, for example, is especially suited for right angle input-output arrangements and high stepdown ratios within a minimum of space.

A new form of skewed axis gearing, Figure 1, covers about the same breadth of applications as do conventional wormgears, Figure 2, but is radically different in form and appearance. This gearing is designated as "Spiroid" and consists of a tapered pinion or worm and a large gear or wheel. The wheel is a face gear resembling spiral bevel or hypoid gears. In spite of their visual resemblance to spiral bevel gears, however, Spiroid gears are definitely in the wormgear family, suited for right angle drives of 10:1 and larger ratios. The Spiroid design has these advantages when compared with conventional wormgears: more liberal mounting tolerances, backlash control, ease of manufacture, added capacity, and shock resistance.

Backlash control

The Spiroid pinion has a lead angle (i.e., the angle made by the screw thread with a plane perpendicular to its axis), pressure angle, and thread form that do not vary over its length. These characteristics are advantageous in two respects. First, its uniform teeth make the pinion easy to manufacture, and the gear can be simply cut by means of a hob resembling the pinion. Second, the spacing between gear and pinion is not critical. The teeth will mesh properly even if assembly tolerances are not tightly held.

The pinion taper is required to insure proper tooth contact over its length and is normally fixed at 5 deg on a side or 10 deg included angle. The face gear is also beveled slightly. It is the combination of bevel and taper that makes Spiroid gearing inherently adjustable for control of backlash. As pinion and gear are adjusted axially, the tightness of mesh is reduced or increased. In Figure 1 for example, the effective diameter of the pinion increases as it moves axially toward the gear axis. This of course tends to take up backlash. Conversely, moving the pinion

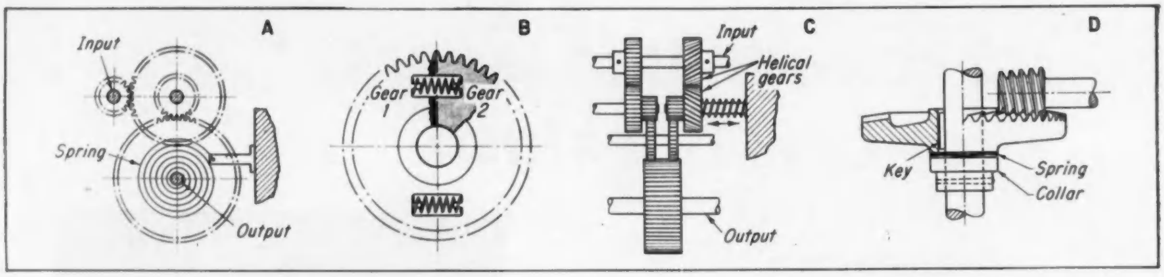


FIG. 3. Gear arrangements for low backlash.

axially out from the gear increases the "daylight" between mating teeth.

Many systems have been developed to eliminate backlash in gear trains. In cases where the number of turns are limited, the systems can be loaded in torsion with a spring or weight, causing the gears to contact one side of the tooth only, Figure 3A. For continuous rotation a useful device is the split gear assembly, which consists of two identical gears on a common axis, Figure 3B. The gears are spring loaded so that a tooth of the mating gear is trapped between them. A variation of this employs two separate gear trains, Figure 3C. All of these systems use a spring or weight system strong enough to overcome the maximum reverse torque anticipated and thus consume a substantial amount of the input energy. In addition, the devices add complexity. Spiroid gearing, on the other hand, can be loaded perpendicularly to the plane of output motion by a simple collar and a spring, Figure 3D.

Efficiency

In Spiroid sets approximately 10 percent of the teeth on the gear are in simultaneous contact with corresponding teeth on the pinion. In a wormgear set only about two teeth of the gear contact the pinion at the same time, and only one tooth of each gear is in full contact in a set of spur gears. The greater number of contacting teeth is reflected in the increased torque transmitting capabilities of Spiroid gears as well as in greater resistance to shock loads. In addition, this design leads to quieter operation and higher accuracies because minor tooth-to-tooth fluctuations tend to cancel one another when averaged over the greater number of teeth. These lines of contact are radial on the pinion threads and extend from root to tip on the gear teeth, Figure 4. They are generally perpendicular to the direction of the sliding motion between gear tooth and pinion tooth. The lines move rapidly across the useful tooth areas of both pinion and gear so that freshly lubricated tooth surfaces are continuously being brought into contact. The nature of this contact is conducive to a corrective lapping process which may be used during manufacture of gears with critical backlash tolerances.

The efficiency of Spiroid gearing varies from over 90 percent for low ratios to only 20 percent for very high ratios. Efficiencies and load carrying ability are approximately the same in both directions of pinion rotation. Where the gear is called upon to drive (overrun) the pinion, efficiency is a much more rapidly changing function, becoming zero at ratios near 30:1. Ratios above 30:1 are generally considered nonoverrunning or self locking.

There are three basic reasons for the good average efficiencies of this type of gearing. A gearset of a given load capacity has a smaller average pinion diameter and, therefore, a larger lead angle than its cylindrical wormgear equivalent. And the continuously shifting line of contact assures well lubricated surfaces that tend to decrease frictional losses. A third and unique reason is that the frictional force is a vector producing a useful torque moment in the direction of gear rotation, while in wormgear sets this force retards motion, Figure 4.

The ratio range of Spiroid gears is bounded at the low end only by the difficulty of manufacturing the tapered pinion and the cutting tools. For practical reasons, they are not produced in ratios much below 10:1. The upper end of the range is limited only by size and efficiency requirements of the particular application. The 360:1 ratio gearset illustrated in Figure 5 has 33 teeth in simultaneous full depth contact. A wormgear of this ratio has

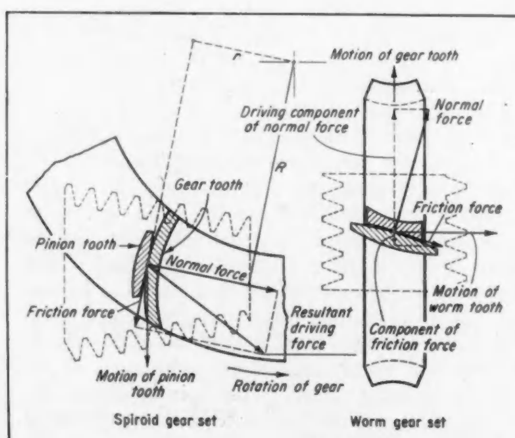


FIG. 4. Mechanics of tooth engagement for Spiroid and worm gearsets.

correspondingly fine pitch teeth but restricted load capacity because only two or three teeth are in simultaneous contact. This type of drive can be employed only where reserve power is available because efficiencies are 25 percent or less at the ultrahigh ratios.

Applications

The precision attainable with the new type of gearing is evident from its use in the headstock of a machine for checking helical broaches. The function of the gears was to turn a broach accurately for lead measurement. The precision attained in this application was ±6 sec of arc. Such close control was required because the helical lead of the broaches was less than one convolution in a 6-ft length. Therefore a small angular inaccuracy in positioning the broach would result in a large transverse error.

Spiroid gearset of 216:1 ratio replaced four sets of spur gears at the output end of a redesigned 500,000:1 reduction for the Regulus missile. In addition to the weight saving, the 20 sec accuracy of the output stage permitted the substitution of less accurate gears in the preceding stages without exceeding the cumulative tolerance specified for the entire reduction. This same quality of gearing was employed in an instrument for checking missile guidance systems. The accuracy obtained in a 359:1 ratio gear was ±3 sec of arc over a small sector.

Poor operation of control systems can sometimes be traced to lack of smoothness in a gear train. In an aerial camera, for example, fluctuations in the angular velocity of gears caused a ripple on the film. It was possible to produce mated gears with such a low angular velocity fluctuation that this error was completely eliminated. The double reduction gearing consisted of an 87:1 primary and a 138:1 secondary, or an overall reduction of 12,006:1. At the lower end of the ratio range, the feed and table drives of the tape-controlled Kearney & Trecker Milwaukee-Matic manufacturing machine employ three sets of Spiroid gears. These 9¼:1 ratio sets rotate ball leadscrews and transmit 7 hp with a minimum backlash variation of less than ±0.0015 in. at a 3¼-in. radius.

Spiroid gears can also be employed in minimum backlash applications where only motion is transmitted. An example is a Motorola tuning drive, Figure 6, which incorporates a molded nylon gear with a small "wavey" spring washer behind the gear. This eliminates backlash and compensates for a small amount of warpage of the nylon gear and runout in the pinion. In a similar application, the gears are assembled tight enough to exclude backlash; run-out is accommodated by deflection in the web of the nylon gear. The molded nylon gears and chased or rolled pinions are the cheapest way to get hand operated, zero backlash gear reduction.

Certain systems have employed Spiroid gears in very high reductions. A Navy test device, for example, includes a 360:1 sector gear set to permit movement through precise angles or increments of angles quickly and with minimum effort. In a second application a single-step 468:1 gearset turns the head on a tape-controlled drilling machine. Here excess torque is available and input inertia is much greater than load inertia; thus the inefficiency of this high reduction is not a problem. Such high ratio drives are usually selected on the basis of convenience and cost despite the fact that they have a lower machanical efficiency than other ways of handling the same reduction.

A special case is a design calling for a high reduction despite limited available power. An example is a radar antenna drive, which has the additional requirement for a relatively large output gear made necessary by the size of the existing antenna drive shaft. Figure 7 shows the gearset selected to meet these specifications. It consists of a large diameter, narrow face gear and a small diameter pinion. The efficiency of the 90:1 set is 74 percent.

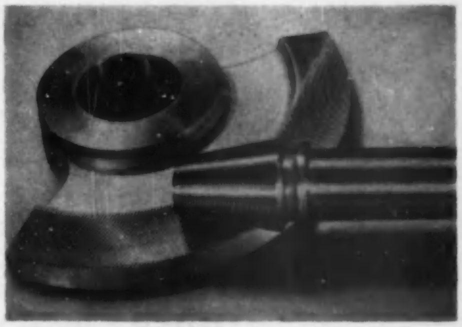


FIG. 5. Sector gear and pinion in 360:1 speed reduction.

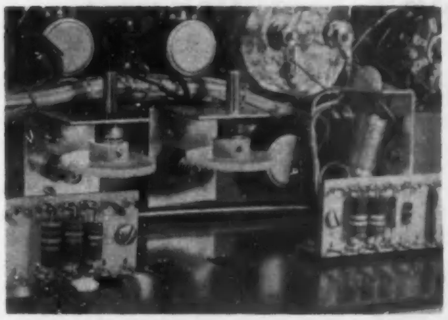


FIG. 6. Nylon right angle gearing employed in Motorola tuning drive provides high ratio in compact space.

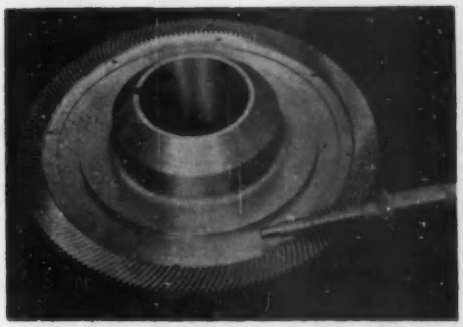


FIG. 7. Right angle gearset provides 90:1 reduction in one step and accommodates large diameter output shaft.

Money isn't everything

. . . *inexpensive* *Fenwal Temperature Controls solve hundreds of temperature control problems*

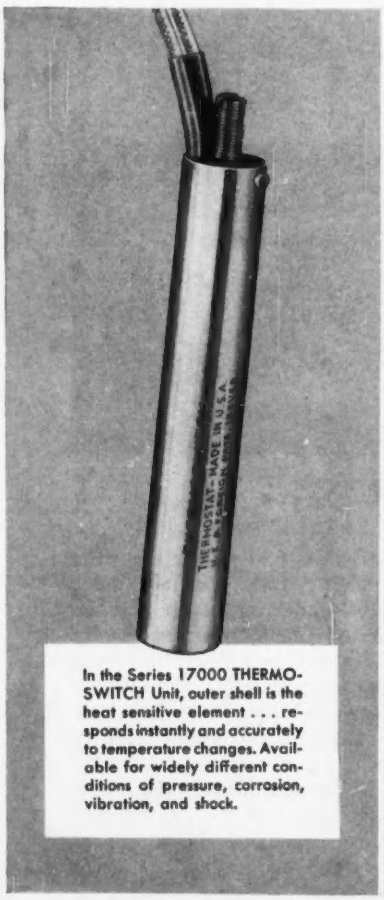
You can control heat precisely within a fraction of a degree in applications ranging from simple plating tanks to 4-circuit systems with Fenwal instruments. Easy to install, completely dependable, they improve process and product *at a fraction of the cost of "complicated" controllers!*

Take the three shown below. The Series 17000 THERMO-SWITCH® Unit represents a versatile family that covers virtually every temperature control situation in fluids and solids. *Available in thousands of variations!*

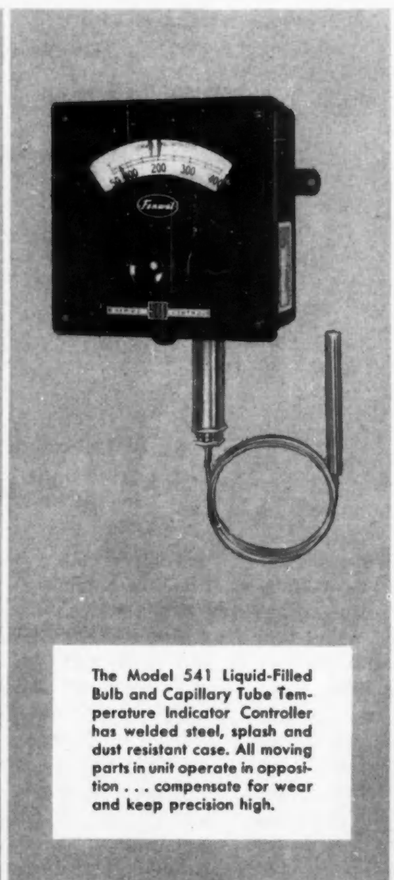
The 541 Temperature Indicator Controller installs in minutes . . . sets with a turn of the control knob. Available in 5 temperature ranges, it provides every detail for *your* particular needs, *from tamper-proof control adjustments to large, easy-to-read dial!*

And for long, dependable performance, nothing matches the 535 Temperature Controller. Thermistor sensor with virtually unlimited life feeds into rugged, transistorized printed circuit. *High precision . . . troublefree operation!*

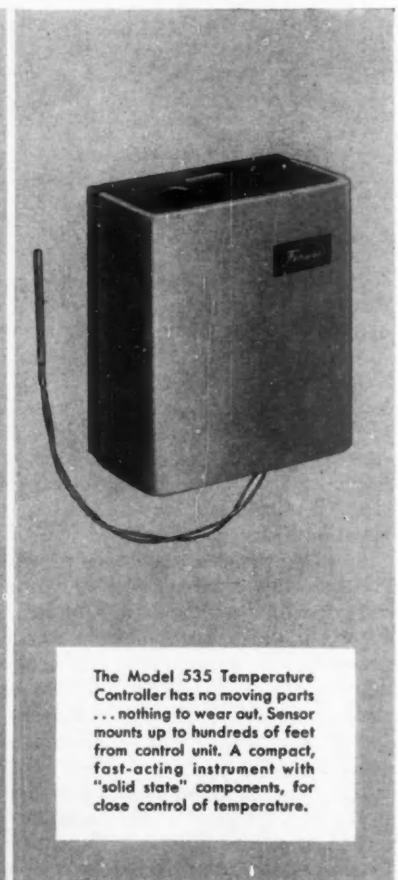
Send for helpful booklet: Precision Temperature Control in Industrial Plants. Write Fenwal Incorporated, 291 Pleasant Street, Ashland, Massachusetts.



In the Series 17000 THERMO-SWITCH Unit, outer shell is the heat sensitive element . . . responds instantly and accurately to temperature changes. Available for widely different conditions of pressure, corrosion, vibration, and shock.



The Model 541 Liquid-Filled Bulb and Capillary Tube Temperature Indicator Controller has welded steel, splash and dust resistant case. All moving parts in unit operate in opposition . . . compensate for wear and keep precision high.



The Model 535 Temperature Controller has no moving parts . . . nothing to wear out. Sensor mounts up to hundreds of feet from control unit. A compact, fast-acting instrument with "solid state" components, for close control of temperature.

ANOTHER EXAMPLE OF HOW **Fenwal** CONTROLS TEMPERATURE . . . PRECISELY

Simple Digital Servo Programs Process Controller Set-Points

J. F. SHARP,
Lindars Automation Ltd., England

Stepping switches are easily programmed from punched tape to give a digital spatial reference from the resulting wiper position. But their normal unidirectional rotation precludes them from general use in positioning systems where the approach to the required position must be bidirectional.

Such a requirement exists, for example, in the programming of boiling pan temperatures where each temperature controller must be set to 50 different temperatures between 130 and 180 deg F for varying time intervals. Analog methods to achieve the required 1 deg accuracy involve high accuracy self-balancing servos and stabilized power supplies. A simple digital servo of two 50-position stepping switches and 52 diodes is the answer.

As the system requirements call for the slave stepping switch wiper to home to the desired position in the shortest distance, relative positions of the command and slave wipers of the stepping switches must provide direction-of-rotation information, Figure 1.

Each contact of the command stepping switch S_1 is linked to the equivalent contact on the slave switch S_2. With the command wiper at position 6 and the slave at position 3, only the positive half-cycles of the energizing supply are operative. These energize relay *B* to step the slave switch to position 4 where it is again energized, stepping the wiper ultimately through to position 6. At position 6 the ac voltage applied via the direct connection to the command wiper now energizes both relays. These in turn energize the stop relay C. Counterclockwise rotation of the slave wiper towards the balance uses the supply negative half-cycles to energize relay A.

Figure 2 shows the tape-controlled digital servo as used to program the temperature of six boiling pans by adjusting individual controller set-points. Tape information first sets the address stepping switch to energize the appropriate controller and motorized set-point drive circuits. Further tape data rotates the 50-position command stepping switch to the required set-point. The out-of-balance position of the slave wiper energizes a 1/40-hp motor coupled to the controller set-point shaft, rotating the set-point shaft and the wiper of the slave switch in discrete steps toward balance.

Where a preset time period for various temperatures is required, the tape reader brings a timer into the circuit to inhibit the tape advance for the required interval.

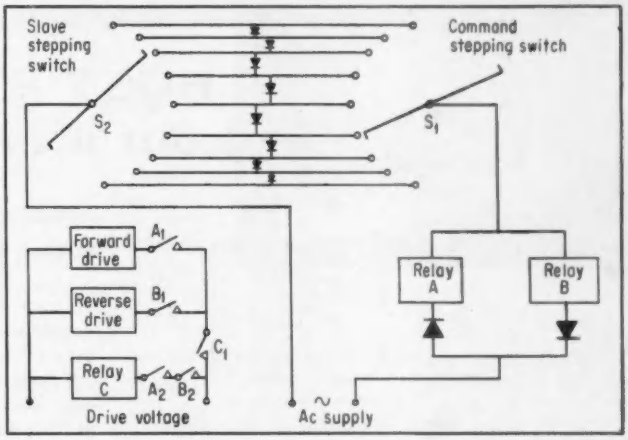


FIG. 1.
Using an ac supply and opposed diodes on direction relays adapts conventional stepping switch to a digital self-balancing servo.

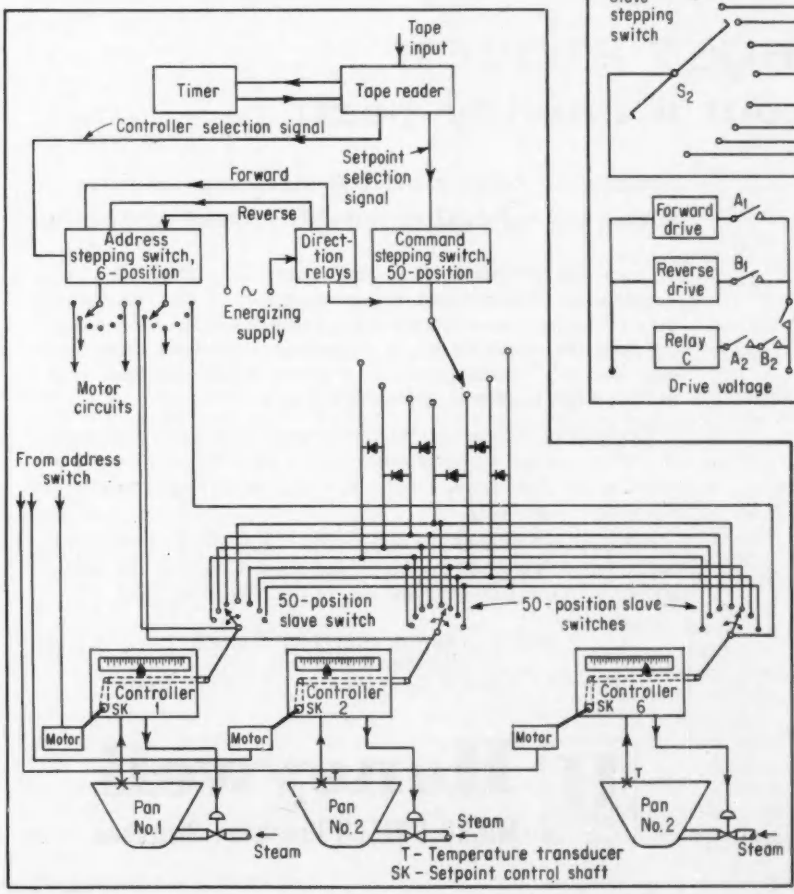
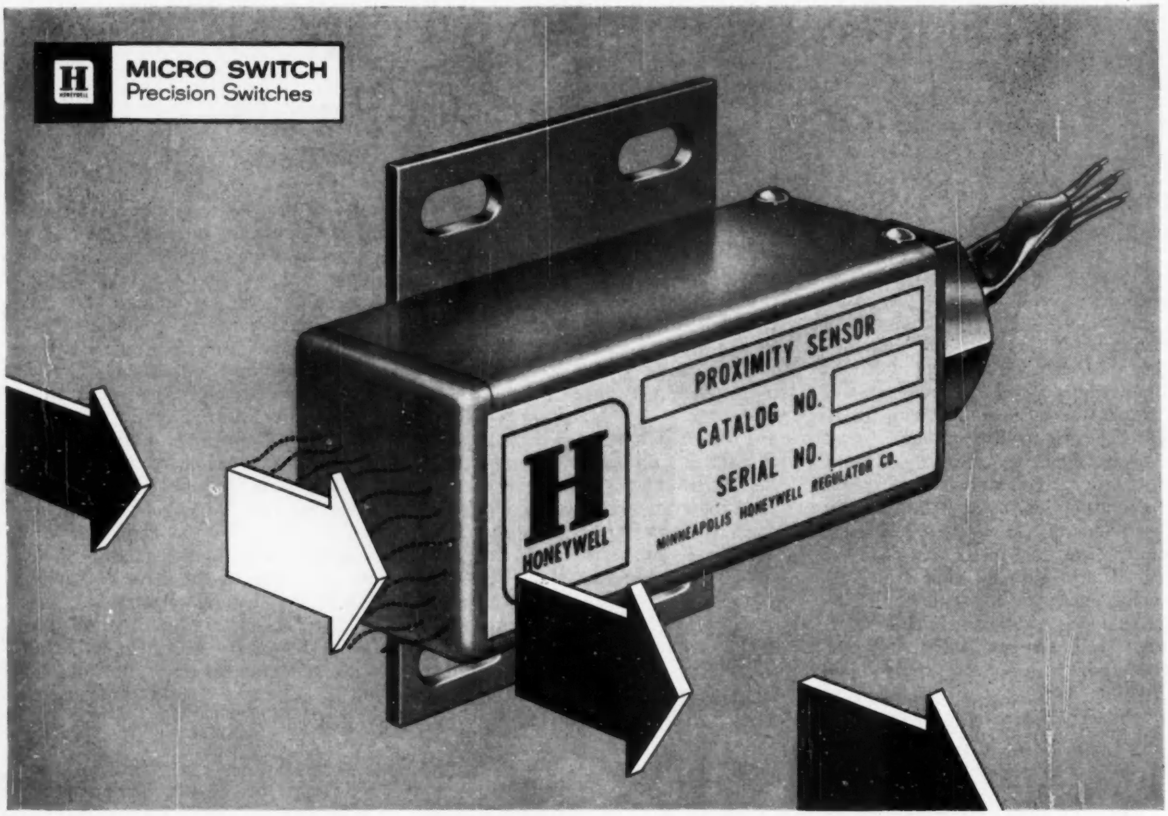
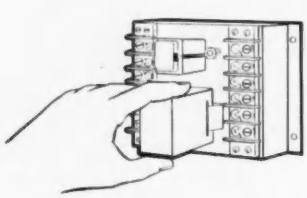


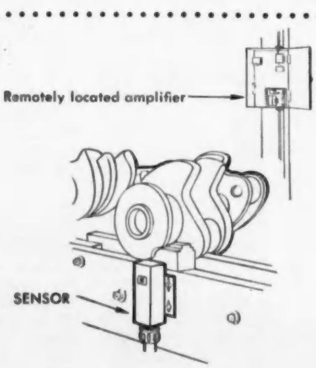
FIG. 2.
Only modifications to apply stepping switch servo to program the temperatures of boiling pans is the addition of a motor drive to each controller set-point shaft plus pickoffs to rotate the 50-position slave switches. All other components are standard items.



BUSY SWITCH
without a moving part!



Plug-in relay in amplifier cuts downtime.



Amplifier is separate, may be remotely located.

Honeywell Proximity Switch opens new ideas for up-dating machines and methods

This amazing new switch solves many automation problems that previously could not be tackled. It detects metal parts that pass within ½" of the sensor—over 600 operations a minute—without ever touching them. Perfect answer where rough parts or corrosive atmosphere may damage a mechanical switch or where the delicate finish of a product might be marred by physical contact.

The Honeywell sensor has no moving parts to wear out, need never be replaced! It has a rugged stainless steel face. The sensing unit is sealed against cutting oils, filings, humidity, sand and dust, can operate submerged if necessary.

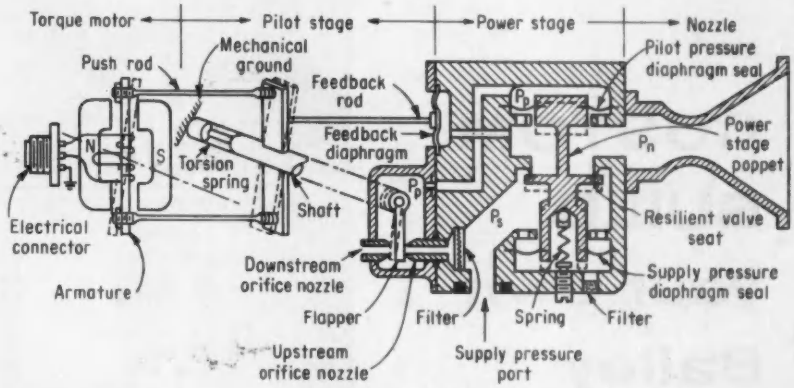
A Proximity Switch can be your answer to difficult switch problems, but be sure it is a product of Honeywell research. Contact the nearby MICRO SWITCH branch office and ask for Data Sheet No. 163.

MICRO SWITCH, FREEPORT, ILLINOIS
A division of Honeywell
In Canada: Honeywell Controls Limited, Toronto 17, Ontario

Honeywell
HONEYWELL
MICRO SWITCH Precision Switches

Reaction Controllers Maintain Attitude of Space Vehicles

C. B. SUNG
B. R. TEITELBAUM,
Bendix Aviation Corp.,
Research Laboratories Div.



Proportional cold gas reaction controller uses variable nozzle first stage which controls a diaphragm-operated poppet valve.

A cold gas reaction controller has been developed for the spatial orientation control system of satellites and high altitude vehicles. The flight control of an aircraft is achieved by the appropriate actuation of control surfaces while the orientation of high altitude vehicles can only be controlled by the use of reaction controllers or their equivalent. So far, the majority of the controllers in use are of the on-off type. The use of porportional type reaction controllers results in much higher performance of the attitude control systems of space vehicles.

The reaction controller discussed here produces thrust proportional to a dc signal by discharging compressed nitrogen through a nozzle. Maximum thrust capacity is 20 lb and maximum signal power is ⅓ watt. The controller weighs 17.5 oz.

Emphasis was placed on compactness and reliability. The use of compressed nitrogen as the power source results in high reliability and minimizes handling and storage problems. On the other hand, the low specific impulse of nitrogen and the heavy weight of high pressure storage tanks call for controllers of extremely low quiescent leakage. The low leakage requirement tends to increase the deadband, which is detrimental in a high performance proportional system.

In the development of the Bendix Model F reaction controller, the design techniques for high performance fluid-power servomechanisms have been used extensively. As a result, it has met all of the apparently paradoxical performance requirements. The cold gas system may actually be competitive weightwise with a hot gas system for missions of certain durations.

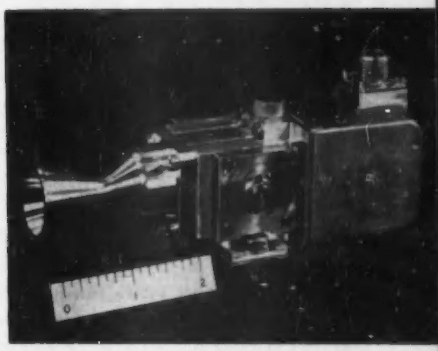
Principle of operation

The closed-loop system is made up of two stages and operates on a torque balance principle. It is illustrated schematically in the drawing. In the pilot stage the torque motor converts a signal current to a torque exerted on the rocker arm. The pilot flapper, mounted rigidly on the same shaft as the rocket arm, is then moved away from the upstream pilot nozzle. As a result, the flow of gas into the pilot pressure (P_p) region from the supply increases, and flow out of the region through the downstream pilot nozzles decreases. (A seal around the rocker arm-flapper shaft restricts all flow out of the pilot pressure region to that through the downstream pilot nozzle.) The effect of the flapper motion is to raise the pilot pressure.

The pressure developed by the pilot stage acts on one side of a rubber diaphragm seal to move the power stage valve poppet away from the resilient seat, opening the power stage valve. The spring at the opposite end of the poppet is compressed and closes the power stage valve when the pilot pressure is reduced.

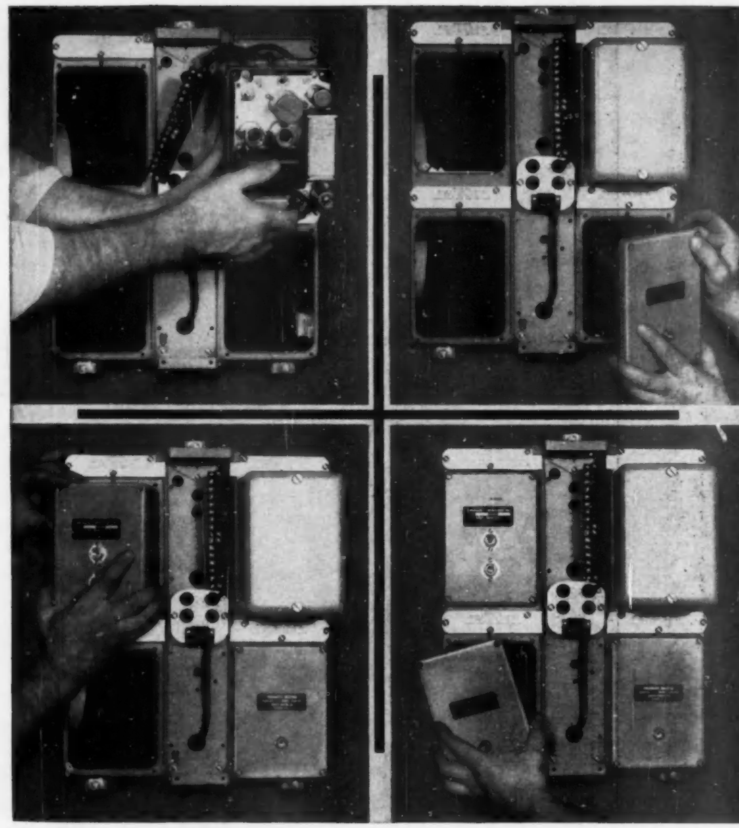
A second diaphragm seal, at the end of the poppet opposite the pilot pressure diaphragm, prevents supply pressure gas from escaping. Both diaphragms are sized so that their effective areas match the area enclosed by the power stage valve sealing circle. Thus all forces on the poppet due to supply and nozzle pressures P_s and P_n are essentially balanced out.

Closed-loop pressure regulation is achieved by feeding back to the pilot stage the thrust nozzle upstream pressure. This pressure acts on the diaphragm of the feedback link and results in a torque on the pilot stage rocker arm in a direction to decrease the pilot pressure. In essence, because of the high sensitivities of the pilot and power stages, the reaction controller produces an upstream nozzle pressure whose feedback torque is substantially equal and opposite to the electromagnetic torque produced by the signal current. A linear and repeatable thrust vs signal characteristic is thereby obtained in spite of variations in supply pressure, nonlinear diaphragm and valve seal behavior, and nonlinear gas flow regimes.



The moving members of the pilot stage are mass balanced to neutralize the effects of vibration and acceleration. Quiescent gas consumption through the thrust nozzle is eliminated by positive sealing of the power stage valve against a resilient seat. Quiescent gas consumption through the pilot stage is minimized by metal-to-metal contact between lapped surfaces of the pilot upstream nozzle and flapper. The measured upstream leakage is less than 0.0003 lb per min.

CUSTOM BUILD your own Bailey Recorder



These four views of the back of a Bailey Recorder show how four plug-in units may be added as needed to meet almost any recorder application.

The freedom and flexibility of "do-it-yourself" instrumentation is yours in the Bailey Recorder. A variety of plug-in units make it possible to record, control, and retransmit any variable that can be converted to a pneumatic or electric signal.

The basic plug-in units are the Bailey a-c and d-c Electronic Receivers and Pneumatic Receivers. Any four of these may be used in one recorder, intermixed in any way, to provide four continuous records on one chart.

For automatic control, other plug-in units are available.

For square root extraction or linear integration, there are two plug-in variations of the Bailey Integrator.

When you want a pneumatic signal that varies according to a pre-set pattern plug in a Bailey Program Controller.

Periodic running time of a condition or process is recorded on the chart when a Bailey Running Time Recorder is used.

These and other plug-in units are described in Product Specification E12-5. Some companies stock Bailey Recorder cases and assorted plug-in units. As instrumentation and control needs arise they build up the kind of recorder-controller required, using the proper plug-in units from stock. Unmatched versatility such as this means lower instrumentation costs.

For the complete story of how easily you can custom build this recorder to your needs, see your Bailey Engineer.

G43-1

BAILEY METERS

Instruments and controls for power and process

BAILEY METER COMPANY

1079 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

Measuring Mega-Ampere Transient Currents

CLELLAND D. NAIL
University of California
Radiation Laboratory (Livermore)

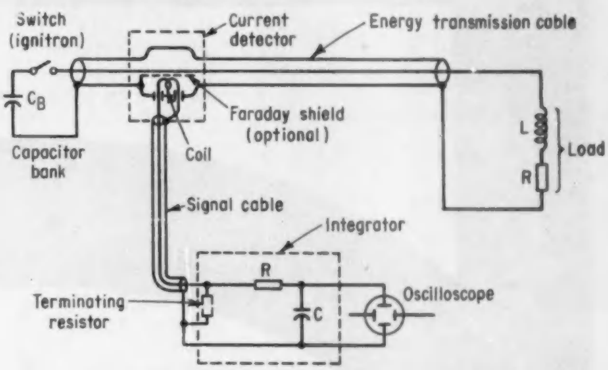


FIG. 1. Capacitor bank at left products high current transient discharge into load circuit at right. Current can be measured as shown by toroidal pickup coil inserted in to coaxial line.

Large transient currents are of increasing interest in many areas of research. For example, in plasma physics research for the eventual production of controlled thermonuclear energy, the techniques for heating and containing the reaction ingredients depend on very high currents and correspondingly high magnetic fields. In extremely high speed photography, large current discharges in gas-filled tubes produce very intense pulsed-light sources of illumination. Since these applications represent instantaneous power levels of billions of watts, such currents can only be created in a transient manner, usually from the discharge of energy accumulated more slowly in a capacitor storage bank. Cummings (Reference) describes a typical bank with a peak power level of over seven times the total installed electrical generating capacity of the entire United States.

Discharges from large capacitor banks into low impedance loads may create currents of more than 10^6 amp. Since such systems are necessarily designed for low inductance and resistance, it is important that any measuring instrument does not appreciably increase the losses or the impedances of the system.

The main disadvantage in measuring current with a shunt is lack of isolation between the current-carrying circuit and the measuring circuit. For very large discharge currents it is very difficult to prevent ground loop currents causing large erroneous signals to be "seen" by the oscilloscope. In practice, it is possible to overcome this disadvantage by 1) floating the oscilloscope ground at the potential reached by the shunt ground or 2) isolating the circuits using a carefully designed coupling transformer. Both are inconvenient; they can be hazardous and introduce errors and frequency dependence.

A fundamentally new solution to the problem of current measurement that does not suffer from the limitations of the current shunt is shown in Figure 1. This approach makes use of the changing magnetic field which surrounds a conductor through which a changing current is flowing.

The magnetic field between the inner and outer conductors of a coaxial cable has the same magnitude as the field produced about an isolated conductor carrying the same current. The difference is that the isolated conductor produces a magnetic field extending throughout all space which diminishes directly with the distance out, while in a coaxial line the field obeys this law only in the space between the conductors, diminishing rapidly to zero in the thickness of the walls of the cable. This is very useful to know, since the field at any point *within* the coaxial region is predictable from the

FIG. 2.
Development version of current detector.

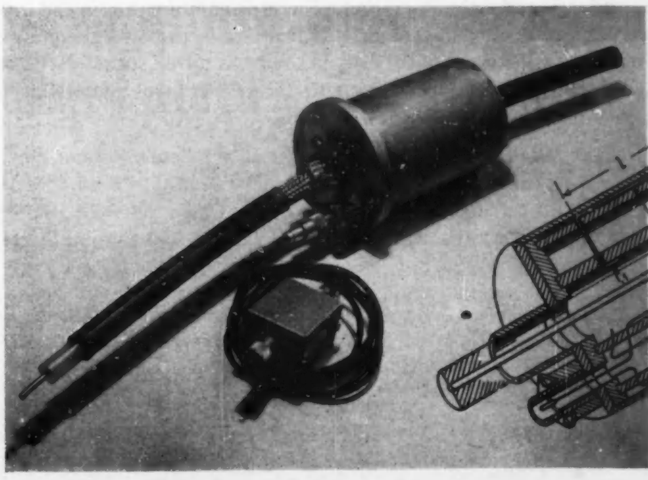
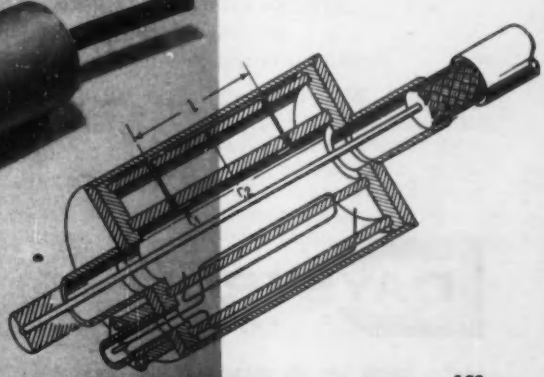


FIG. 3.
Sectional view showing the internal structure of the current detector in Figure 2.



very simple formulas for isolated conductors (the law of Biot and Savert).

By enlarging the coaxial structure of a current-carrying transmission line it is possible to place a coil in the predictable field region. The voltage induced in such a coil is the well-known $N d\phi/dt$; that is, it is directly related to the number of turns N and the time rate of change of flux $d\phi/dt$, which is in turn proportional to the time rate of change of current. To obtain a voltage signal directly proportional to the current rather than its rate of change, it is necessary to mathematically integrate the coil voltage as a function of time. This can be done to sufficient accuracy for most applications by the simple RC network in Figure 1.

Calibration factor and design

The calibration factor of a current detector is the ratio of amperes flowing to the signal voltage observed. To be useful, this ratio must be constant during the time of interest and independent of the current magnitude. To fulfill the requirement of time independence, the simple integrator must have a long RC time constant (say 10 times the time of interest). The second requirement, linearity, is achieved by the use of nonmagnetic material so that no core saturation or other nonlinear ferromagnetic properties are encountered and by the use of copper conductors large enough to prevent heating and resistive effects.

The calibration is expressed by:

$$i = \frac{RC}{M} e_c \qquad (1)$$

where i is the instantaneous value of current to be measured in the coaxial conductors, and e_c is the corresponding signal voltage developed across the integrator capacitor C of Figure 1. RC is the time constant of the integrator (ohms $\times$ farads), and M is the mutual inductance between the coil and the coaxial line measured in henries. Thus RC/M becomes the calibration factor for the device.

The calibration factor RC/M may be adjusted to a convenient whole order of magnitude like 10^4 or 10^5 (amperes/volt) by selecting the value of R (or C) for a particular pickup coil design. In this way an awkward factor such as say 3.29×10^4 may be eliminated.

When working with large transient currents, it is not uncommon to experience noise signals of a few millivolts due to pickup on the trigger inputs or the power lines of the oscilloscope. The calibration factor of the current detector should give a signal of a volt or more to make such errors negligible.

For current detector coils of simple rectangular shape, the mutual inductance M can be calculated quite accurately from the dimensions of the coil, using the expression

$$M = \frac{N\mu l}{2\pi} \log \frac{r_2}{r_1} \qquad (2)$$

where N turns are wound on the coil whose rectangular dimensions are:

l = length (in meters)
r_1 = distance of the near side of the coil from the center of the coaxial structure. See Figure 3.
r_2 = distance of the other side of the coil from the center of the line. See Figure 3.
μ = the permeability of the medium (4×10^{-7} henries/meter for nonmagnetic materials).

These equations are developed from classical fundamentals.

It is usually most convenient to locate the integration network immediately adjacent to the oscilloscope since the output from the integrator is of relatively high impedance, unsuited to drive a transmission line. Small coaxial cable may be used between the coil and the integrator, and a terminating resistor for this line may be built into the can or housing for the integrator, Figure 1.

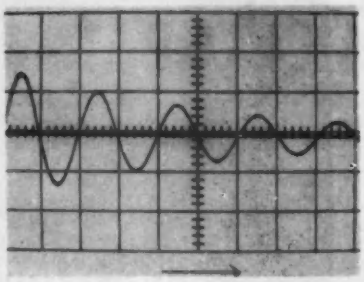


FIG. 4. The integrated voltage signal from the current detector is proportional to the instantaneous current. Initial peak is 7,000 amp.

A current detector developed for experimental work is illustrated in Figure 2 with the internal arrangement shown in Figure 3. This unit was designed to slide over RG/17U coaxial cable. Lateral movement of the conductor from a central position has almost no net effect upon the coupling between the conductor and the coil. The coil consists of 10 turns and has a mutual inductance of 1.5×10^{-9} henries.

A typical oscillogram obtained with this detector is shown in Figure 4. This picture was obtained using a 15-millisec integrator (15 kilohms $\times$ 1 μfd) and shows a peak current at the first maximum of 7,000 amp. The calibration factor is 100,000 amp/volt.

REFERENCE

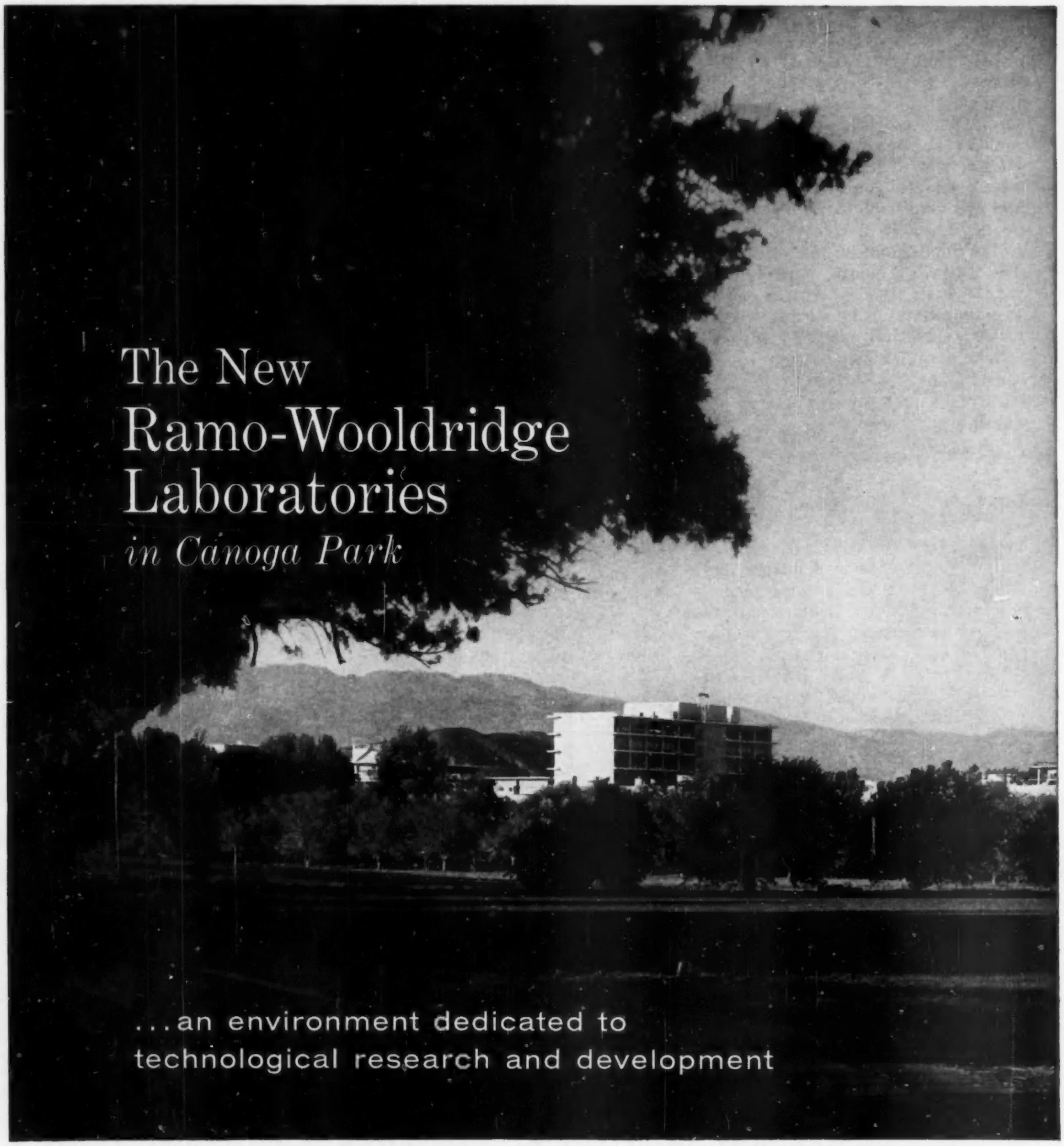
DEVELOPMENT OF SWITCHING COMPONENTS FOR CONTROLLED FUSION RESEARCH, D. B. Cummings, Report USRL-5411, University of California Radiation Laboratory. Published in "IRE Transactions on Nuclear Science", Sept. 1959.

Reader-Computer-Plotter Link Saves Data Reduction Time

A Burroughs E101 electronic computer has joined hands with an automatic plotter and oscillograph and film record readers in a unique data reduction operation. Perforated paper tape serves as the tie-in for the highly mechanized set up at Hughes Aircraft Co.'s Culver City, Calif., plant. Here's how it works:

Raw flight test data comes in as an oscillograph record which is fed into a special reader, where values of key points are recorded on perforated paper tape. The tape is then fed into the E101, which beats the data against an appropriate prepinned program. The reduced output data, again on perforated paper tape, is taken to another reader, which feeds through a converter for output to an automatic plotter. Besides reduction of flight test data for systems evaluation, the busy computer tackles jobs in computer controls radar, communications, electronic tube research, ground systems, and human engineering.

In pre-E101 days, the data reduction staff used seven desk calculators, tried to get an engineer's problem solved within a week. Now next-day service is typical.



The new Ramo-Wooldridge Laboratories in Canoga Park, California, will provide an excellent environment for scientists and engineers engaged in technological research and development. Because of the high degree of scientific and engineering effort involved in Ramo-Wooldridge programs, technically trained people are assigned a more dominant role in the management of the organization than is customary.

The ninety-acre landscaped site, with modern buildings grouped around a central mall, contributes to the academic environment necessary for creative work. The new Laboratories will be the West Coast headquarters of Thompson Ramo Wooldridge Inc. as well as house the Ramo-Wooldridge division of TRW.

The Ramo-Wooldridge Laboratories are engaged in the broad fields of electronic systems technology, computers, and data processing. Outstanding opportunities exist for scientists and engineers.

For specific information on current openings write to Mr. D. L. Pyke.

THE RAMO-WOOLDRIDGE LABORATORIES

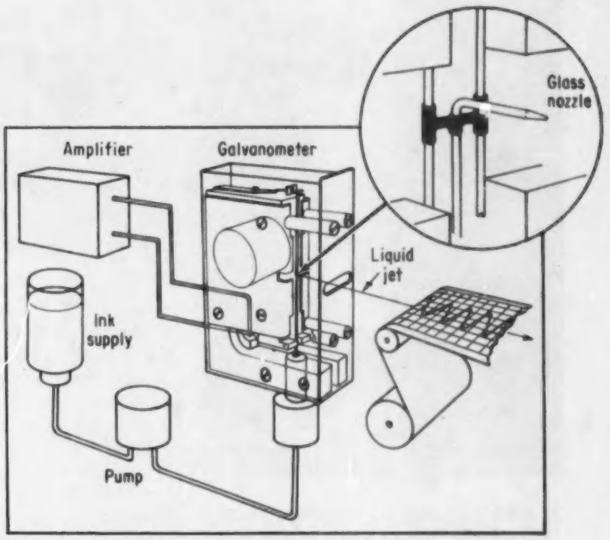
8433 FALLBROOK AVENUE, CANOGA PARK, CALIFORNIA

NEW PRODUCTS

GERMAN OSCILLOGRAPH ups response.

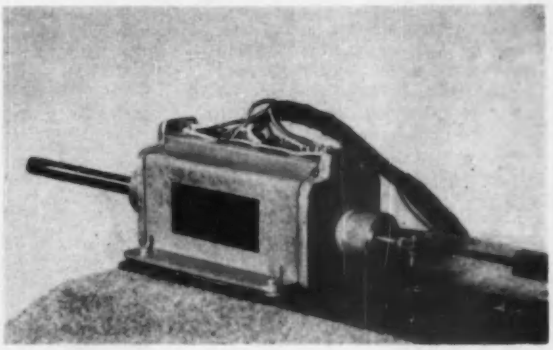
Developed by Siemens & Halske AG, West Germany, the Oscillomink galvanometer-type oscillograph extends the limited frequency response of the pen-recording type of instrument. Instead of a pen arm the galvanometer drives a low inertia glass nozzle which squirts a liquid jet of ink (0.0004-in. diam) onto the recording paper. Since this free jet contributes nothing to the moment of inertia of the moving system, natural frequency of the system is about 650 cps. A compensating circuit in the associated amplifier provides a further extension to about 800 cps.

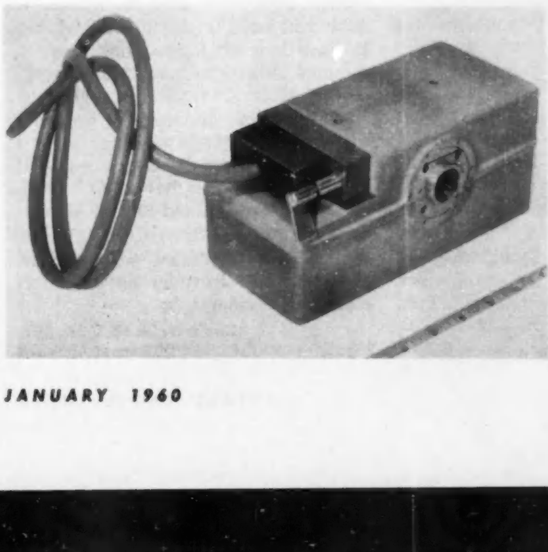
The instrument's detecting system resembles that of the loop vibrator in a conventional light-beam oscillograph. In place of the light source and mirror, however, the new instrument uses a glass capillary tube and nozzle as shown in the sketch to the right. The tube is fixed at its lower end so that torsion developed serves as a mechanical restoring force. Pressure of the ink may be adjusted according to the recording speed. A synchronous motor drives the paper feed.—Siemens & Halske AG, Erlangen, West Germany. **Circle No. 280 on reply card.**



LINEAR STEPPING MOTOR provides accurate positioning.

Photo at right shows the Model B1002 linear positioning motor, a new dc actuator designed to translate simple input signals into discrete linear positions. The device is magnetically operated but, unlike a solenoid, it will hold a 2-lb force in any one of 27 positions along its 2⅛-in. stroke length. For continuous duty it requires 24 watts at 115 vdc and features a repeatability within 0.003 in. It may also be operated on an 11 percent intermittent duty cycle at 300 vdc, in which case it will provide a 6-lb holding force for up to 4 min.—Tronics Corp., Minneapolis, Minn. **Circle No. 281 on reply card.**





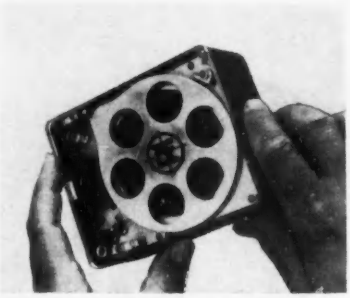
NEW ENCODER retains last reading.

Called a Mem-O-Tizer, this new angle encoder houses an integral input shaft and from one to three code drums. Each drum contains a series of concentric cams profiled to provide any of the major data codes. On readout command, solenoid-operated fingers sense the drum profiles and simultaneously position switches which provide the coded output. Fingers retract within 50 msec, but the switches retain their position until the next readout. Lost motion couplers permit readouts to be made while the input shaft is turning at 250 rpm. On typical two-drum unit, breakaway torque is only 0.004 oz-in.—Telechrome Mfg. Corp., Amityville, N. Y.

Circle No. 282 on reply card.

NEW PRODUCTS

DATA HANDLING & DISPLAY



TWO-POUND RECORDER

Photo above illustrates the compact design of a new subminiature, two-channel magnetic tape recorder. The complete instrument occupies less than 40 cu in., weighs 2 lbs, and draws only 2½ watts from a dc source. It uses 4-in. coaxially stacked reels which hold 900 ft of ¼-in. tape. Features include tape speeds to 48 ips in either direction, end-of-tape sensing, and a frequency response to 160 kc.—Precision Instrument Co., San Carlos, Calif.

Circle No. 283 on reply card

EASILY INSTALLED

Suitable for both scientific and business data processing, the new RPC-4000 general purpose digital computing system will soon be available at a monthly rental of $1,750 or a total sales price of $87,500. This includes the computer and standard input-output equipment. Fully transistorized, the system involves no site preparation or installation costs. The system can operate on 9-digit numbers at rates up to 240,000 operations per min. Its tapered magnetic drum memory rides on a cushion of air, has a storage capacity of 8,008 words (32 useable bits per word), and may be charged for full or partial words at a sustained rate of nearly 200,000 words per min. Complete basic system draws less than 10 amps from a standard 110-volt line and weighs less than 1,000 lbs.—Royal McBee Corp., Port Chester, N. Y.

Circle No. 284 on reply card

INDICATOR-TOTALIZER

Designed for remote indication of both batch and cumulative weights, this compact dust-tight instrument combines an indicator and single unit totalizer. As the indicator pointer rotates, the counter is driven through an electric clutch and suitable gearing to totalize pounds of material. Depending on the capacity and readability desired, the 6-digit counter can have a graduated-units wheel, one or more dormant zeros, or a decimal point. It completely eliminates the need for computations when on-the-spot flow checks are required.—Richardson Scale Co., Clifton, N. J.

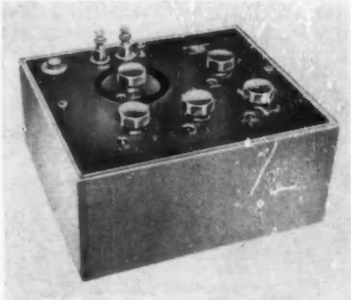
Circle No. 285 on reply card

PLUS . . .

(286) Performance Measurements Co., Detroit, Mich. has announced a **digital torque indicator** that integrates torque fluctuations to produce a true average readout. . . . (287) The Series 3000 apertured **ferrite plate memory stacks,** a line of miniature magnetic storage plug-in modules developed by **Rese Engineering, Inc.,** Philadelphia, Pa., are designed for use in high speed random access memories and serial buffers. . . . (288) A new **digital recording system,** designed for the automatic testing of vacuum tubes on a mass production basis, is available from **Dates Corp.** Monrovia, Calif. . . . (289) The **Heiland Div.** of Minneapolis-Honeywell Regulator Co., Denver, Colo., has added a 24-channel model to its Visicorder line of **direct recording oscillographs.**

Circle No. 286, 287, 288, or 289 on reply card

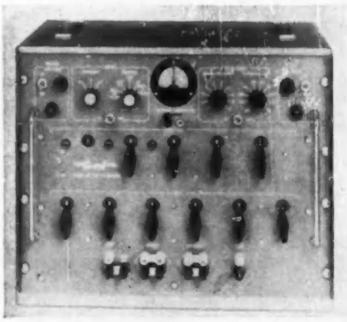
RESEARCH, TEST & DEVELOPMENT



RESISTANCE STANDARDS

A new series of H. W. Sullivan non-reactive resistance standards features guaranteed accuracy within 0.01 percent from dc to at least 50 kc, without corrections of any kind and without reference to calibration certificates. Model AC 440, pictured above, covers the range of 11,111 ohms in 0.1-ohm increments. Other models are available with from one to five dials, increments as small as 0.01 ohm, and ranges up to 100,000 ohms.—British Industries Corp., Port Washington, N. Y.

Circle No. 290 on reply card

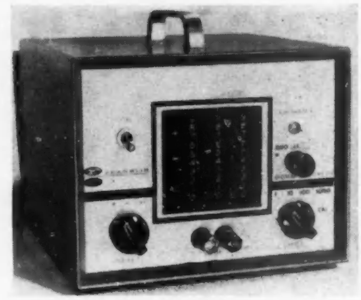


RATIO BRIDGE

Designed for testing 3- or 4-terminal networks such as transformers, synchros, resolvers, gyros, and transducers, this new complex ratio bridge cancels quadrature effects and gives a sharp true null. In-phase ratio accuracy is within 0.001 percent. Quadrature voltage ratios are read as rectangular coordinates, as the tangent of the phase angle, or as the phase angle in deg. A self-contained phase-sensitive detector provides excellent sensitivity with only a 2-volt reference. A suitable band-pass filter rejects both noise and harmonics. Available frequency ranges are 30 to 1,000 cps and 50 to 3,000 cps.—Gertsch Products, Inc., Los Angeles, Calif.

Circle No. 291 on reply card

NEW PRODUCTS

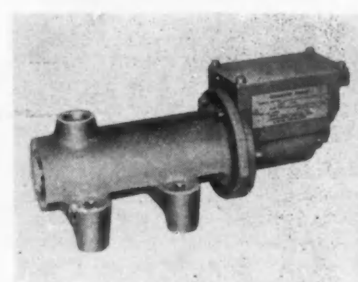


PARTLY TRANSISTORIZED

Said to be the smallest ever built, this Model 201 digital voltmeter is completely electronic in operation, partly transistorized, and free of mechanical step switches or similar devices. Its accuracy is within 1 percent of full scale on all dc ranges and within 2 percent on ac ranges for frequencies between 50 cps and 600 kc. Features include automatic polarity indication for dc voltages, mercury cell calibration, internal print-out connections. Priced at $375, the unit weighs 11 lb and measures 6½ in. high, 8½ in. wide, and 8¼ in. deep—Franklin Electronics, Inc., Van Nuys, Calif.

Circle No. 292 on reply card

PRIMARY ELEMENTS & TRANSDUCERS

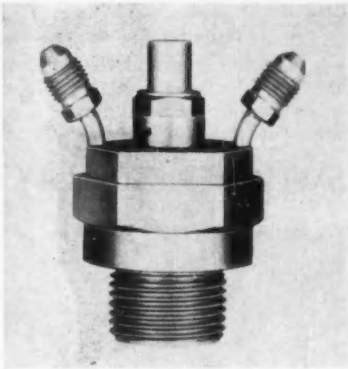


FOR REACTOR LOOP

Designed for use in the primary loop of pressurized water nuclear reactors, this new pressure transmitter consists of a differential transformer whose core is positioned by water pressure acting on a spring-loaded piston. Normally a bellows on the stem of this piston provides the sealing, but for added safety the entire assembly is confined within an all-welded stainless steel housing. Units are available with

pressure ranges of 0 to 500 psi, 0 to 1500 psi, and 0 to 2500 psi; either ac or dc output voltages may be specified. For nonnuclear applications, carbon steel models are available.—Consolidated Controls Corp., Bethel, Conn.

Circle No. 293 on reply card



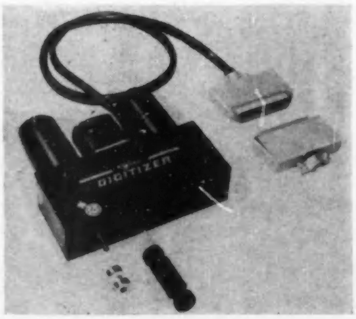
SOUND LEVEL PICKUP

Photo above shows a Model 752 water-cooled microphone transducer, developed for measuring high level sounds under severe environmental conditions. Statically calibrated, the device may be used in remote control operations at up to 1,200 ft. or more.

Characteristics:

Ambient temperature range: minus 85 to plus 400 deg F
Diaphragm temperature range: minus 250 to plus 2,000 deg F
Frequency response: 0 to 10,000 cps
Sound pressure ranges available: 180 to 228 db
—Photocon Research Products, Pasadena, Calif.

Circle No. 294 on reply card



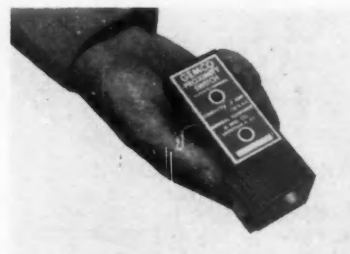
VERSATILE ENCODER

This Decimal Digitizer, a nonambiguous electromechanical shaft position encoder, provides straight decimal contact output. Features include continuous or demand readout, five speeds between 10 and 1,000 counts per rev-

olution, and the direct operation of parallel entry printers. Units are available with 3-, 4-, 5-, or 6-decade outputs.—Coleman Electronics, Inc., Gardena, Calif.

Circle No. 295 on reply card

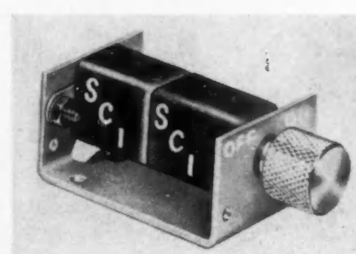
CONTROLLERS, SWITCHES, & RELAYS



NEW PROXIMITY SWITCH

Containing only one moving part, this compact proximity switch operates without coils, relays, or amplifier. Hermetically sealed within its brass housing are an Alnico magnet assembly, an armature assembly, and one pair of spdt contacts rated at 2 amps at 125 vac. Capable of operating at over 30,000 cycles per min., this switch is said to have an operating life expectancy equal to that of systems costing 2½ times as much. Its temperature range is from minus 50 to plus 250 deg. F; repeatability, within 0.002 in. of set operating point.—General Equipment & Mfg. Co., Inc., Louisville, Ky.

Circle No. 296 on reply card

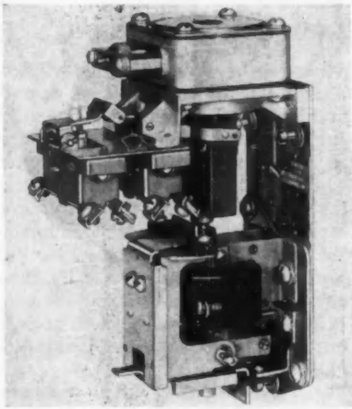


RELIABLE SWITCHING

The Magneswitch, a brand new concept in miniature switches, actually consists of two separate hermetically sealed elements. One of these, the actuator, contains a permanent ceramic

magnet and a pair of permeable pole pieces that collects and conducts the magnetic flux. The other element contains a similar pair of pole pieces, an armature, and a snap action switch. Switching action occurs when the pole pieces of both elements are aligned. Photo above shows one of many possible figurations. Here the switch is fixed to a panel mounted bracket, and the actuator rotated by means of a control knob. For limit switching applications, switching can be attached to a fixed member and the actuater carried by a moving member. No physical contact is required. Contact readings of 5, 10, and 15 amps are available. – Space Components, Inc., Washington, D. C.

Circle No. 297 on reply card



RATIO CONTROLLER

Available in both indicating and recording models, the new 60000 Series ratio controller contains two primary elements, a control mechanism, and a ratio unit which is actuated directly by changes in the independent variable. Its ratio unit consists of a linkage which varies the control point of the dependent variable with changes in the independent variable. When the desired ratio has been selected, it will be maintained by the control action.–Mason-Neilan Div., Worthington Corp., Norwood, Mass.

Circle No. 298 on reply card

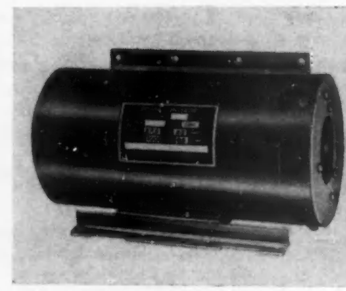
NEW TIMING RELAY

Two spdt snap switches provide two normally open and two normally closed timed contacts in this adjustable range pneumatic timing relay. Each switch can be separately adjusted for a different timing sequence. Timing range is adjustable from 0.2 sec. to 3 min; repeat accuracy is within 10 percent. Units are available for either ac or dc operation.–Square D Co., Milwaukee, Wis.

Circle No. 299 on reply card

IMPORTANT: Circle key numbers below and mail before April 1, 1960

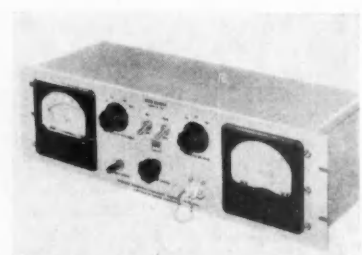
POWER SUPPLIES



NEW CONVERTER LINE

Photo above shows one model from a new line of transistorized dc-to-dc and dc-to-ac converters designed for the direct replacement of dynamotors in both military and commercial equipment. Units weigh approximately ½ as much as the dynamotors they replace and completely eliminate the problem of brush wear. Over full load and continuous duty cycles, these converters have an operating temperature range from minus 55 to plus 85 deg C.—The Daven Co., Livingston, N. J.

Circle No. 300 on reply card



NEW BIAS SUPPLY

Designed for testing IR photo conductors, this battery-operated ISL 501 bias supply features extreme low-noise capability and linear precision meters. The unit may be used with photoconductors or thermistor voltmeters. Availability of a microammeter in conjunction with a voltmeter makes it possible to measure the resistance of a detector under actual operating conditions. Standard voltage ranges are 50, 100, and 500 volts; current ranges are 25, 100, 250, and 1000 μa.—Infrared Standards Lab., Riverside, Calif.

Circle No. 301 on reply card

IMPORTANT: Circle key numbers below and mail before April 1, 1960

	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
1	11	21	31	41	51	61	71	81	91	101	111	121	131	141	151	161	171	181	191
2	12	22	32	42	52	62	72	82	92	102	112	122	132	142	152	162	172	182	192
3	13	23	33	43	53	63	73	83	93	103	113	123	133	143	153	163	173	183	193
4	14	24	34	44	54	64	74	84	94	104	114	124	134	144	154	164	174	184	194
5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195
6	16	26	36	46	56	66	76	86	96	106	116	126	136	146	156	166	176	186	196
7	17	27	37	47	57	67	77	87	97	107	117	127	137	147	157	167	177	187	197
8	18	28	38	48	58	68	78	88	98	108	118	128	138	148	158	168	178	188	198
9	19	29	39	49	59	69	79	89	99	109	119	129	139	149	159	169	179	189	199

200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390
201	211	221	231	241	251	261	271	281	291	301	311	321	331	341	351	361	371	381	391
202	212	222	232	242	252	262	272	282	292	302	312	322	332	342	352	362	372	382	392
203	213	223	233	243	253	263	273	283	293	303	313	323	333	343	353	363	373	383	393
204	214	224	234	244	254	264	274	284	294	304	314	324	334	344	354	364	374	384	394
205	215	225	235	245	255	265	275	285	295	305	315	325	335	345	355	365	375	385	395
206	216	226	236	246	256	266	276	286	296	306	316	326	336	346	356	366	376	386	396
207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
209	219	229	239	249	259	269	279	289	299	309	319	329	339	349	359	369	379	389	399

☐ Enter my subscription to CONTROL ENGINEERING for one year and bill me for the $5 cost

Name Title

Company

Address City Zone State

One of these handy prepaid post cards will bring you detailed information

GET

More Information About

1. Advertised products

2. New product items

3. Catalogs and bulletins

All advertisements, new products and literature items are numbered for your convenience.

IMPORTANT: Circle key numbers below and mail before April 1, 1960

	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
1	11	21	31	41	51	61	71	81	91	101	111	121	131	141	151	161	171	181	191
2	12	22	32	42	52	62	72	82	92	102	112	122	132	142	152	162	172	182	192
3	13	23	33	43	53	63	73	83	93	103	113	123	133	143	153	163	173	183	193
4	14	24	34	44	54	64	74	84	94	104	114	124	134	144	154	164	174	184	194
5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195
6	16	26	36	46	56	66	76	86	96	106	116	126	136	146	156	166	176	186	196
7	17	27	37	47	57	67	77	87	97	107	117	127	137	147	157	167	177	187	197
8	18	28	38	48	58	68	78	88	98	108	118	128	138	148	158	168	178	188	198
9	19	29	39	49	59	69	79	89	99	109	119	129	139	149	159	169	179	189	199

200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390
201	211	221	231	241	251	261	271	281	291	301	311	321	331	341	351	361	371	381	391
202	212	222	232	242	252	262	272	282	292	302	312	322	332	342	352	362	372	382	392
203	213	223	233	243	253	263	273	283	293	303	313	323	333	343	353	363	373	383	393
204	214	224	234	244	254	264	274	284	294	304	314	324	334	344	354	364	374	384	394
205	215	225	235	245	255	265	275	285	295	305	315	325	335	345	355	365	375	385	395
206	216	226	236	246	256	266	276	286	296	306	316	326	336	346	356	366	376	386	396
207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
209	219	229	239	249	259	269	279	289	299	309	319	329	339	349	359	369	379	389	399

☐ Enter my subscription to CONTROL ENGINEERING for one year and bill me for the $5 cost

Name Title

Company

Address City Zone State

HOW TO USE THESE CARDS:

1. Find the key number on item of interest
2. Circle this number on one of the cards
3. Mail card immediately

Postage Will be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY MAIL

First Class Permit No. 64, (Sec. P. L. & R.) New York, N. Y.

Reader Service Department 1 (1-60)

CONTROL ENGINEERING
330 WEST 42nd Street
New York 36, N. Y.

INSTRUCTIONS

Use these reader service cards to get more information on advertised products, new product items or catalogs and bulletins appearing in Control Engineering

Postage Will be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY MAIL

First Class Permit No. 64, (Sec. P. L. & R.) New York, N. Y.

Reader Service Department 2 (1-60)

CONTROL ENGINEERING
330 WEST 42nd Street
New York 36, N. Y.

1.

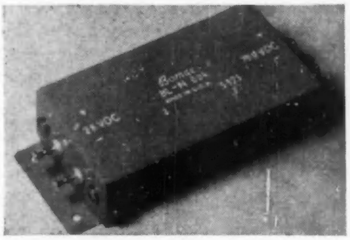
Circle number on card that coincides with key number listed at bottom or adjacent to item of interest.

2.

Fill in your name, title, company and address.

3.

Mail card immediately.



KEEP-ALIVE POWER

The BL-N-004 keep-alive supply pictured above operates from a 28 vdc source and can supply up to 170 μa at 750 vdc. Its output voltage is held to within 3 percent for any input voltage between 22 and 34 volts. A 4.7 megohm resistor limits the output current. Both input and output terminals are isolated from the case.—Bomac Laboratories, Inc., Beverly, Mass.

Circle No. 302 on reply card

PLUS . . .

(303) **The Superior Electric Co.**, Bristol, Conn., has introduced a new electromechanical automatic **voltage regulator** designed to meet Mil-E-4158 B specifications. . . . (304) Two high quality, **high voltage power supplies,** using selenium rectifiers and rated at 0-3 volts, have been announced by **Kilovolt Corp.**, Yonkers, N. Y. . . . (305) A new line of precision high **temperature power supplies,** developed by the **Arnoux Corp.**, Los Angeles, Calif., features operating temperature ranges between minus 55 and plus 120 deg. C.

Circle No. 303, 304, or 305 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS

SOLENOID-ACTUATED

Suitable for use on steam, air, and liquid lines at pressures to 250 psi and temperature to 450 deg F., a new line of solenoid actuated pressure regulating valves offers a combination of on-off control and normal pressure regulation. When the solenoid valve located in the outlet pilot tube is open, process fluid operates the main valve as a normal pressure regulator. When

NEW PRODUCTS

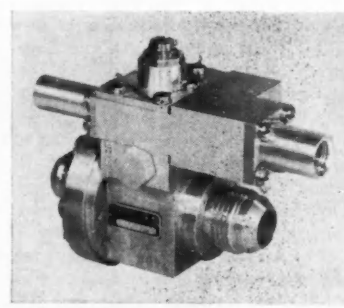
the solenoid valve is closed, however, full pressure of the process fluid in the inlet pilot tube closes the main valve. Sizes are from ½ to 3 in.—OPW Jordan Corp., Cincinnati, Ohio.

Circle No. 306 on reply card

NEW VALVES OPERATOR

A brand new valve operator for electronic process control applications uses an electric motor and fully electronic control circuits. Frequency response, transfer characteristics, torque, and thrust are equal to those of pneumatic operators. Adaptable to a wide variety of valve types, the new operator is capable of stroking speeds up to ½ ips. — Industrial Equipment, Inc., Newark, N. J.

Circle No. 307 on reply card



ZERO LEAKAGE

Pneu-Hydro low torque ball valves, for operating pressures up to 10,000 psi, can be furnished with pneumatic, hydraulic, electric, or manual actuators. Pressure operated unit above weighs 1½ lbs., measures 2½ by 4½ by 5 in. long and has an equivalent orifice of ¾ in. Applications include missile ground support equipment and airborne attitude controls.—Pneu-Hydro Valve Corp., Cedar Knolls, N. J.

Circle No. 308 on reply card

PLUS. . . .

(309) **Vickers Inc.**, Detroit, Mich. announces a new 5- to 25-gpm **deceleration valve** for hydraulically actuated machinery. . . . (310) A 12-oz. **electrohydraulic servovalve,** developed by **Kearfott Co., Inc.,** Clifton, N. J., features titanium construction and a rated flow to 7.5 gpm at 3,000 psi pressure drop.

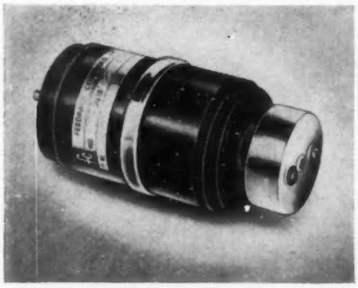
Circle No. 309 or 310 on reply card

COMPONENT PARTS

SWITCHING TRANSISTOR

Designed to meet Signal Corps specifications, the military-type 2N1120 switching transistor will readily dissipate 45 watts at a base temperature of 25 deg C. Its maximum collector current rating of 10 amps and its collector-emitter voltage rating of 70 vdc make it well suited for both high current and high voltage applications. —Bendix Aviation Co., Long Branch, N. J.

Circle No. 311 on reply card



VISCOUS-COUPLED

Designed for applications requiring high velocity and high torque constants with good stability, a new viscous-coupled inertial damper consists of a fly-wheel floated within a low inertial shell. Shell is fastened to a servomotor shaft as shown in the photo above. Viscous fluid between fly-wheel and shell provides the damping action. Models are available with outside diameters of 1.52 and 1.79 in. and with 10 time constants ranging from 0.02 to 1.20 sec.—Feedback Controls, Inc., Natick, Mass.

Circle No. 312 on reply card

PLUS. . . .

(313) **Brown Instruments Div.**, of Minneapolis-Honeywell Regulator Co., Philadelphia, Pa., is now marketing a new **magnetic amplifier** designed for current-proportioning control instruments used in heat treating operations. . . . (314) A new line of encapsulated **toroidal transformers**, developed by **Barker & Williamson, Inc.**, Bristol, Pa., is said to be well suited for use in transistorized power supplies. . . . (315) **Northern Union, Inc.**, Arcadia, Calif., offers a ½-oz. adjustable **slip clutch** with a torque range of from 0 to 100 oz-in.

Circle No. 313, 314, or 315 on reply card

BULLETINS AND CATALOGS

NOTE: This month's Bulletins & Catalogs section starts with several items for which written requests are necessary. Complete addresses are given for these. For any other item, circle appropriate number on reader reply card.

SERVO MANUAL. Superior Mfg. & Instrument Corp., 154-01 Barclay Avenue, Flushing 55, New York. Offered as an engineer's handbook and servosystem specification guide, this 40-page manual was prepared to simplify the design and procurement of servomechanisms and their integration into more complex systems. Contains five technical sections including a number of detailed design sheets arranged to assist the engineer in precise specification of positioning, velocity, or integrating servos and synchro transmission systems. Tables of significant relationships, conversion factors, and illustrative examples are provided as an aid for determining performance requirements.

FERRITES AND THEIR USES. Kearfott Co., Inc., 1500 Main Ave., Clifton, N. J. This 20-page technical article, prepared by Dr. L. Brady and J. E. Zneimer of Kearfott's Solid State Physics Laboratory, covers typical applications of ferrites in missiles and advanced electronic equipment. Well illustrated and carefully referenced, it discusses the use of ferrites in microwave devices, motor components, electromechanical filters, mechanical filters, and traveling wave tubes.

MAGNETIC CLUTCHES. PIC Design Corp., 477 Atlantic Ave., East Rockaway, L. I., N. Y. Entitled "Magnetic Clutches and their Applications", this 18-page booklet provides an interesting discussion on the design, operation, and proper use of magnetic clutches and clutch brakes. Tables and graphs contain specifications and performance data at various operating temperatures and voltages.

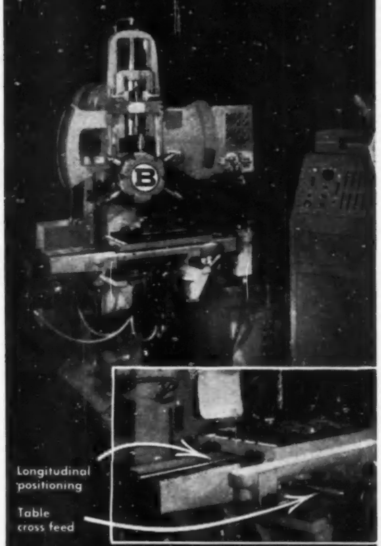
(350) WIDTH GAGES. Daystrom, Inc. Bulletin 13-203, 4-pp. Details equipment and operating principles of a new infrared gage system which measures and records the width of hot strip traveling at speeds up to 2,000 fpm.

(351) PROCESS DATA SYSTEM. Hagen Chemicals & Controls, Inc. Bulletin MSP-161, 12 pp. Provides a complete description of the Kybernetes Series 2000 Data System, an all-electronic package designed to perform logging, monitoring, computing, and optimizing control operations. Includes general specifications and a typical system block diagram.

(352) PRECISION VALVES. Hydra-Power Corp. Brochure, 8 pp. Covers a wide variety of hydraulic and pneumatic control valves designed for missile, aircraft, and other airborne applications. Photograph accompanies brief description of each product.

(353) ANALOG COMPUTER. Boonshaft & Fuchs, Inc. Bulletin, 4 pp. Describes a Swiss-made analog computer, the AR-2. Covers operation, design features, and component characteristics. Photograph illustrates all front panel controls.

(354) ELECTRONIC ACCESSORIES.



Bulletins & Catalogs

Atlas E-E Corp. Engineering catalog, 56 pp. Consolidates a number of brochures, price lists, and dimension drawings covering the company's complete line of electronic accessories. Typical sections cover fuse and resistor clips, diode clips, tube shields, tube holders, inserts, battery holders, etc.

(355) GERMANIUM DIODES. General Transistor Corp. Brochure GD-40, 10 pp. Features include characteristic forward and reverse curves and typical specifications for a complete line of germanium gold bonded diodes. Drawing illustrates major construction details.

(356) FORMULA CAPSULE. Richardson Scale Co. Product Data Sheet 5904, 2 pp. Describes and lists advantages of the company's new formula capsule, a miniature electronic package for controlling up to 24 different materials in automatic batching operations.

(357) VOLTAGE RATINGS. General Electric Co. Bulletin GEC-1450A, 60 pp. Provides useful application and selection data on GE's redesigned dry and liquid filled Inductrol voltage regulators for 60- and 400-cycle applications.

(358) FURNACE CONTROLS. Minneapolis-Honeywell Regulator Co. Bulletin B43-1C, 40 pp. Complete with prices, booklet covers a wide variety of furnace and oven controls. Products include ElectroniK potentiometers, millivoltmeters, thermocouples, Radiamatic detectors, thermometers, as well as flame safeguard systems, industrial controls, and final control elements.

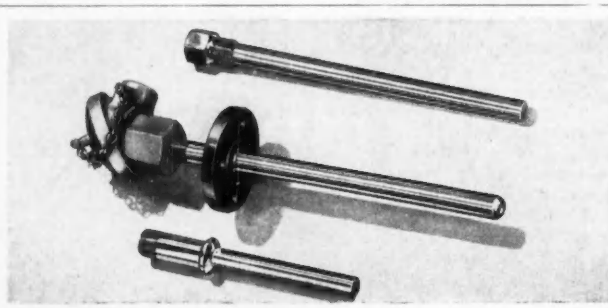
(359) ANNUNCIATOR SYSTEMS. Panellit, Inc. Catalog 100C, 52 pp. Organized for quick reference, bulletin is said to provide the most comprehensive single source of information on annunciator systems ever published.

(369) PULSE INSTRUMENT. Electro-Pulse, Inc. 1959-60 general catalog, 48 pp. Contains complete technical information on a broad range of pulse instrumentation, including general purpose pulse generators, word generators, time delay generators and electronic counters. Two detailed technical articles deal with factors affecting selection and application.

(361) BREADBOARDING SYSTEM. Gap Instrument Corp. Catalog 2, 12 pp. points out the advantages of a new servo breadboarding system which eliminates the need for conventional gear diagrams, layouts, and small quantity machining. Illustrates both stock components and technical assemblies.

(362) RESISTOR DATA. Reon Resistor Corp. Engineering catalog, 24 pp. Contains strictly technical data on the performance characteristics of precision wire-wound and composition variable resistors. Charts and tables should be of particular interest to application engineers.

(363) THERMOCOUPLE CATALOG. Leeds & Northrup Co. Catalog EN-S2, 52 pp. Newly revised bulletin presents complete information on a full line of thermocouple assemblies, components, and accessories. Discusses advantages and limitations of various protecting tube and well materials.



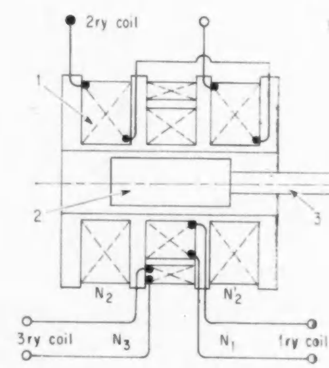
ABSTRACTS

A Japanese development

From "Four Coil Type Differential Transformer" by Tadashi Akiyama and Yutaka Ino. Journal of the Society of Instrument Technology, Japan, pp. 354-358, June 1959. (In Japanese.)

Differential transformers for null balance measurement are said to have several disadvantages including extremely poor interchangeability due to phase difference between reference signal and measurement signal. The four coil type differential transformer was developed especially for null balance measurement and has a third coil to act as a reference signal source.

Figure 1 shows the basic construction of the four coil differential transformer (FCDT). Four coils are wound on a phenol resin or hard ceramic coil



spool. The primary coil N_1 wound in the center is connected to the exciting power supply. Secondary coils N_2 and N'_2 wound at the right and left of N_1 are arranged in reverse polarity and connected to the output circuit. A tertiary coil, N_3, is connected to the balancing voltage slidewire. A ferrite core (2) and a core rod (3) are placed between the coils and move along the coil axis. Within the range where proportional relationship between core displacement and secondary voltage e_2 is maintained, tertiary voltage e_3 would remain constant. Since variation in voltage, frequency, and waveforms affects either the secondary or tertiary output voltage equally, and ambient temperature change affects the output of either coil as well, compensation of these factors can be accomplished by forming an automatic null balancing network with equal load on each coil, as shown in Figure 2.

When the FCDT is used as a trans-

ducer, complete temperature compensation provided on the transducer itself would suffice. However, when it is employed in such applications as a pressure gauge or load cell utilizing a primary element which measures deformation of elastic material, complete temperature compensation for the ele-

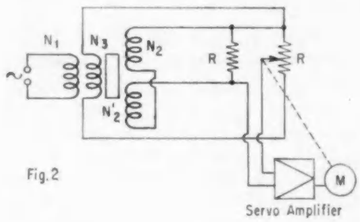


Fig.2

ments including temperature coefficient of the elastic material would be required. Since the temperature coefficient on the modulus of elasticity of spring steel is plus 0.025 to 0.035 percent per deg C, the temperature coefficient compensation of the FCDT can be established at minus 0.275 percent per deg C, keeping the overall temperature coefficient within plus or minus 0.0025 percent per deg C. In the circuit shown in Figure 3, a fixed resistor whose value is m times as large as the resistance of the coil is connected

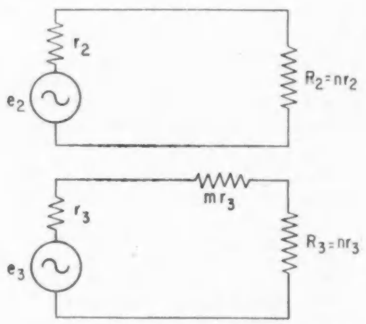


Fig. 3

across the tertiary coil. Assuming that the resistance temperature coefficient of the coil is α, the resistance temperature coefficients of the secondary and tertiary coils are $\alpha/(1+n)$, and $\alpha/(1+m+n)$ respectively. Therefore, the temperature coefficient δ may be established so that m and n satisfy:

$$\delta = \alpha/(1+m+n) - \alpha/(1+n)$$

Alignment when incorporating FCDT into an automatic null balancing instrument can be accomplished by a span potentiometer adjustment. It is not necessary to consider phase relationship as in a conventional differential transformer.

Translated and abstracted by
Kazuto Togino

NEW BOOKS

Important Text

DIGITAL AND SAMPLED-DATA CONTROL SYSTEMS. *Julius T. Tou, Purdue University. 631 pp. Published by McGraw-Hill Book Co., Inc., New York.* $15.

This book was written to provide scientists, engineers, and system analysts with a comprehensive, well organized, and up-to-date account of the basic theory and available techniques for the analysis and design of digital and sampled-data control systems and related problems. Much of the material in this book has previously been available only in various technical journals or proceedings of conferences. This volume is largely the outgrowth of a set of lecture notes for a two-semester course offered to graduate students. An adequate preparation in an introductory course on feedback control systems and a sound knowledge of Laplace transforms and complex variable theory is assumed. In preparing the text, the author was careful to make many of the chapters selfcontained or partially independent.

Emphasis is placed on the development of basic theory. Many numerical examples are worked out in the text to clarify the development of the theory and to illustrate the discussion of the various methods. Approximately 70 problems of various types and complexity are included as is a list of references which covers the contributions of many workers in the field. A feature is an extensive table of transforms and modified transforms.

Quick Refresher

MATHEMATICAL ANALYSIS. *Edwin M. Hemmerling, Bakersfield College. 332 pp. Published by McGraw-Hill Book Co., Inc., New York.* $5.75

Specifically written for a one-semester course given in technical institutes, colleges, and junior colleges, this text offers a relatively painless way for the practicing engineer who may have allowed his grasp of mathematics to fade to pick up the traces again. The material provides a survey of the essential knowledge and skills necessary for successful study of calculus; the text begins with fundamental algebraic equations and goes through elements of differential calculus. Particular attention is given to those topics and concepts which technical and pre-engineering students must thoroughly understand before they tackle the study of calculus.

WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Some reprints are individual articles, while others are "packages"—several articles published over a period of time that logically supplement one another in the coverage of a specific phase of the control field. Any reprint can be obtained at the nominal cost listed below by filling in the order form and sending it, together with remittance, to Readers Service Dept. Quantity rates will be quoted on request.

Transparent Template for Designing Servo Compensators, November 1959, 3 pp. plus template. Includes transparent decibel vs phase angle template on clear acetate in addition to three-page Data File outlining development of template and showing its use through sample problem. 75 cents.

How to Use the Root Locus in Control System Design, 12 pp. Another reprint that translates theory into practice. Eight simple rules make locus construction easy, even including the effects of distance-velocity lags. Articles show how to interpret the locus diagram, how to determine transient response, and how to use locus techniques with multi-loop systems. 45 cents.

Complete Analysis Instrumentation Series, 112 pp. Special rate for those who order all three parts (I, II, and III) of Analysis Instrumentation Series; 17 percent discount on 112 pages of timely

Continued on page 176

Reprint Order Form

Reprint	Unit price	No. ordered	Subtotal
Servo Compensator Template	$0.75	......	......
How to Use the Root Locus	$0.45	......	......
Complete Analysis Instrumentation	$1.75	......	......
Analysis Instrumentation—III	$0.90	......	......
Analysis Instrumentation—II	$0.60	......	......
Analysis Instrumentation—I	$0.60	......	......
Fundamentals of Multivibrators	$0.50	......	......
Control System Test Equipment	$0.60	......	......
Ac Adjustable-Speed Drives	$0.50	......	......
A New Way to Select Control Valves	$0.50	......	......
Ready Reference Data File—II	$0.50	......	......
Fundamentals of Tie-Motor Control	$0.30	......	......
How to Use Phase Plane Techniques	$0.50	......	......
Economics in Control	$0.50	......	......
Report on Russian Control	$0.40	......	......
Calculating a Control Index	$0.30	......	......
Servo Design Techniques	$0.65	......	......
Flowmeters	$0.50	......	......
Applying Control Timers	$0.50	......	......
Control System Reliability	$0.20	......	......
Point-to-Point Positioning Systems—I, II & III	$1.50	......	......
Ready Reference Data File—I	$0.50	......	......
Servo Modulators	$0.65	......	......
The Uses of Digital Computers	$3.00	......	......
Basic Data on Process Control	$0.50	......	......
How to Simulate Dead Time	$0.15	......	......
Power Amplifiers	$0.50	......	......
Static Switching Devices	$0.50	......	......

Reader Service Dept., CONTROL ENGINEERING
330 W. 42 St., New York 36, N. Y.

Total......

Name ....

Address ....

City & State..

REPRINTS cont'd

technical information for process control engineers. $1.75.

Analysis Instrumentation—III—Electrochemical Methods, Mass Spectrometry, Continuous Viscometers, X-Ray Techniques, K-Capture, Physical and Chemical Property Testers, Emission Spectroscopy, 48 pp. Reprint includes last nine articles of Analysis Instrumentation Series. $.90.

Analysis Instrumentation — II — Refractometers, Infrared Analyzers, Photometric Analyzers, Colorimetry, 32 pp. This includes the second group of four articles of the Analysis Series. 60 cents.

Analysis Instrumentation — I — Nuclear Magnetic Resonance, Chromatography, Radioactivity, 32 pp. Reprint consists of first 4 articles of Analysis Instrumentation Series: a general introduction and detailed discussions of the three analysis techniques. Emphasis is on basic principles, practical tips, and the use of these techniques in automatic process control. 60 cents.

Fundamentals of Multivibrators, 12 pp. Multivibrators are the electronic equivalent of the double-throw electromechanical relay and can perform substantially the same functions (memory, logic, gating, counting), but at enormously higher speeds. They can be built around vacuum tubes, transistors, square-loop magnetic materials, neon tubes, thyratrons, and cryotrons. This reprint covers a broad selection of multivibrator circuits that are especially applicable to control systems. 45 cents.

A Roundup of Control System Test Equipment, 24 pp. Specialized control system test equipment divides into three classes: 1) devices that only generate a test signal, 2) systems that both disturb the system and provide a means for evaluating response, and 3) devices that only evaluate control system response. A survey of equipment and tips on using it. 60 cents.

Survey of Ac Adjustable-Speed Drive Systems, June 1959, 16 pp. Largely regarded as constant-speed devices, multi-speed ac actuators actually take many efficient forms. The recent resurgence of interest in these ac adjustable-speed systems prompted this comprehensive coverage of pole-changing techniques, armature resistance control of wound-rotor motors, frequency changing, slip-frequency injection, and the use of eddy-current couplings. 50 cents.

A New Way to Select the Best Control Valve, 16 pp. This three-article reprint takes a fresh look at the problem of specifying process flow control valves. The author gives rules for selecting the right valve characteristics based on static and dynamic considerations, takes into account the influence of piping on valve performance, and tackles the problem of sizing valves for maximum flow and for control rangeability. 50 cents.

Ready Reference Data Files—II, 24 pp. Includes the second dozen data files published in Control Engineering. Add it to Ready Reference Data Files—I to keep your personal file up to date. Topics covered range from analyzing hydraulic servos graphically to using silicon diodes as protective devices. 50 cents.

Continued on page 177

REPRINTS cont'd

Fundamentals of Tie-Motor Control, 12 pp. Although high-powered synchro-tie systems have been around for a long time, only recently has enough experience been logged to put their design on a scientific, rather than cut-and-try, basis. This reprint examines the types of motors that can be used in the light of the application characteristics, and considers the special circuit designs that are required. 30 cents.

Applying Phase-Plane Techniques to Nonlinear System Design, 16 pp. This series of three articles is designed to teach the use of phase-plane techniques to working system designers, on a practical rather than theoretical basis. It tells how to construct a phase-plane plot, how to interpret a plot in terms of system performance, and how to synthesize nonlinear systems using phase-plane techniques. 50 cents.

Economics in Control, December 1958, 24 pp. A special report covering the economic aspects of modernizing with control systems. It starts off with a guide to the financial factors of modernization, then tells the control engineer how to spot opportunities where the addition of instrumentation and control equipment will earn money, and concludes with nine case histories showing specific benefits of modernizing with control systems. 50 cents.

First-Hand Report on Control Inside Russia, November 1958, 16 pp. A team of 14 U. S. control engineers representing the American Automatic Control Council reports on the status of automatic control in Russia. Each expert gives impressions of progress in his field of interest based on visits to Russian user plants and research facilities. 40 cents.

How to Calculate a Control Earning Index, 12 pp. Shows a four-step method for predicting the increment of improved plant economy resulting from the addition of instruments and controls, and reports on experience in applying this method to three typical industrial processes. 30 cents.

Servo Design Techniques, 32 pp. A reprint of six related articles describing various electromechanical servo design techniques. Items include tachometer limiting, force-reflecting servos, calculating performance of drag-cup tachs, dual-mode servo compensation, applying packaged servo actuators, and cascading resolvers without amplifiers. 65 cents.

What's Available in Flowmeters, 24 pp. A comprehensive coverage of positive displacement, velocity, and mass flowmeters, including characteristics, applications, and typical manufacturers; plus details of a special drag disc meter. 50 cents.

Selecting and Applying Control Timers, 24 pp. A compilation of four articles including a tabular description of timer functional parts, criteria for selecting and applying control timers, a tabular listing of available timer types and their characteristics, and techniques for custom-designing controls for time-based routines. 50 cents.

• • •

MEETINGS

JANUARY

Sixth National Symposium on Reliability and Quality Control, sponsored by IRE, AIEE, ASQC, and EIA, Statler Hilton Hotel, Washington, D. C. Jan. 11-13

Operations Research Short Course, Case Institute of Technology Campus, Cleveland, Ohio Jan. 18-29

Stress Measurement Methods Symposium, sponsored by Strain Gage Readings (journal), Arizona State Univ., Temple, Ariz. Jan. 25-29

American Institute of Electrical Engineers, Winter General Meeting, New York City Jan. 31-Feb. 5

FEBRUARY

Instrument Society of America, Instrument-Automation Conference and Exhibit, Houston Coliseum, Houston, Tex. Feb. 1-5

Institute of Radio Engineers, Winter Convention on Military Electronics, Ambassador Hotel, Los Angeles, Calif. Feb. 3-5

Seventh Annual Solid-State Circuits Conference, sponsored by IRE, AIEE, University of Pennsylvania, Philadelphia, Pa. Feb. 10-12

MARCH

American Society of Mechanical Engineers, Hydraulic Division Conference (held jointly with Gas Turbine Power Conference), Rice Hotel, Houston, Tex. March 6-9

Instrument Society of America, Temperature Measurement Symposium, Deshler Hilton Hotel, Columbus, Ohio March 9-11

Institute of Radio Engineers, National Convention, Coliseum and Waldorf-Astoria Hotel, New York City March 21-24

22nd Annual American Power Conference, sponsored by Illinois Institute of Technology, Hotel Sherman, Chicago, Ill. March 29-31

APRIL

Sixth Nuclear Congress, sponsored by ISA and Engineers Joint Council, New York City April 3-8

Third National Chemical and Petroleum Instrumentation Symposium, Rochester, N. Y. April 5-7

Conference on Automatic Techniques, sponsored by IRE, AIEE, ASME, Sheraton Cleveland Hotel, Cleveland, Ohio April 18-19

Institute of Radio Engineers, Southwest Regional Conference and Electronics Show, Shamrock-Hilton Hotel, Houston, Tex. April 20-22

Texas A&M Symposium on Instrumentation, Campus, Bryan, Tex. April 20-22

EMPLOYMENT OPPORTUNITIES

NATIONAL COVERAGE

—— RATES ——

DISPLAYED

The advertising rate is $23.80 per inch for all advertising appearing on other than a contract basis. Contract rates quoted on request.

An advertising inch is measured 7/8" vertically on a column—3 columns, 30 inches to a page.

Subject to Agency Commission.

UNDISPLAYED

$2.10 per line, minimum 3 lines. To figure payment count 5 average words as a line. Box Numbers—counts as 1 line.

Position Wanted ads, 1/2 of above rate.

Discount of 10% if full payment is made in advance for 4 consecutive insertions.

Not subject to Agency Commission.

Send NEW ADS and inquiries to Classified Advertising Division of Control Engineering, 330 W. 42nd St., N.Y. 36, N.Y.

---

engineers . . . scientists stretch your imagination

. . . at Beckman Instruments, last refuge of the Non-Organization Man. Here's a company that is concerned with the man, his mind and his original contributions.

Commercial, industrial and military projects tickle the fancy of unconstrained intellects at these Beckman Divisions:

Beckman®
- *Scientific and Process Instruments Division*
- *Systems Division*
- *Helipot Division of Beckman Instruments, Inc.*

Don't get crushed in the Organization Mill . . . look into these imagination stretching positions . . .

ENGINEERS/SCIENTISTS . . .

at all levels in the fields of precision electronic components and analytical instrumentation for engineers and scientists with degrees in engineering or physical science. Some of our specific needs include project engineers, senior scientists or engineers, product engineers and senior electronic engineers. We also have openings for exceptional recent graduates.

And you can stretch your legs in Orange County, too, where you and your family will enjoy Southern California living at its barbecuing best.

Overcome your own organizational inertia . . . phone, wire or write Mr. T. P. Williams for all the parameters.

Beckman® *Instruments, Inc. Fullerton, California © 1960*
Telephone TRojan 1-4848; from Los Angeles OWen 7-1771 B.I.I.

INSTRUMENTATION ENGINEERS

with interest in

PRODUCTION - DEVELOPMENT - RESEARCH

The development and application of instrumentation and automation techniques to production, development, and research programs in Nuclear Energy Installations.

Engineering graduates with experience in electronic or pneumatic process control instrumentation required. Knowledge of data acquisition, system analysis, analytical instruments and measurement standards also desirable.

Exceptional opportunities, competitive salaries, modern and unique facilities, liberal benefit plans, educational and training programs, plant interview and family moving expenses, moderate climate, year around outdoor recreational activities, low cost living, available housing.

OAK RIDGE NATIONAL LABORATORY
OAK RIDGE Y-12 PLANT
GASEOUS DIFFUSION PLANTS,

Oak Ridge, Tennessee, and Paducah, Kentucky

Send your resume to:

UNION CARBIDE NUCLEAR COMPANY

Central Technical Personnel Office, P. O. Box M, Oak Ridge, Tennessee

---

CONTROL APPLICATION ENGINEER

for unusual opportunity with outstanding growth company

We need a capable control application engineer with imagination to generate practical ideas for industrial electronic control devices. Prefer a B.S. in Electrical Engineering. Must be capable of dealing with high level customer contacts. This is a key position of tremendous importance in our Research and Development Department.

Emerson Electric is a dynamic, highly successful growth company. Expansion continues rapidly and surely in the fields of electronics, electric motors, appliances and home builder products. Gross sales of 91 million dollars annually (40 million five years ago) are expected to double in the next five or six years.

Excellent salary is augmented by a liberal employee benefits program, fine working conditions and a stimulating, progressive atmosphere. Beautiful St. Louis County residential areas surround our convenient suburban location. All moving expenses paid by the company.

Send comprehensive resume, including salary requirements and inexpensive photo, to R. L. Middleton. All replies strictly confidential.

ELECTRONICS & AVIONICS DIVISION

EMERSON ELECTRIC

8100 W. FLORISSANT
ST. LOUIS 36, MO.

engineers
and
scientists

LEEDS & NORTHRUP CO.

. . . as a result of continued growth now has openings for college graduates at the Bachelor, Master's and Doctoral level. Electrical, chemical, nuclear or physics degrees preferred.

IF *you enjoy doing creative work at a truly professional level and have 2 to 10 years' experience in:*

- MEASUREMENT & CONTROL OF INDUSTRIAL PROCESSES
- DATA PROCESSING
- ELECTRIC & STEAM POWER
- NUCLEAR REACTORS
- SERVOMECHANISMS
- ANALYTICAL INSTRUMENTATION
- TECHNICAL WRITING
- ANALOG & DIGITAL COMPUTERS
- SOLID STATE ELECTRONICS

We would like to talk to YOU about openings in:

- ***Research & Development***
- ***Sales Engineering***
- ***Product Engineering***
- ***Application Engineering***

Send Your Resume To

MR. WAYNE L. BESSELMAN

Coordinator Of Technical Employment

LEEDS & NORTHRUP CO.

4850 Stenton Ave. • Philadelphia 44, Pa.

OPPORTUNITIES FOR THE YOUNG ENGINEER IN THE INSTRUMENTATION FIELD

Opportunity for young men with 1 to 4 years experience in a plant instrument department.

Assume systems engineering responsibilities working on all types of plants—chemical, refinery, pulp and paper, beverage, steel, power, etc. Follow projects through the feasibility study, flow sheet stage, design and specification, procurement and installation.

Work with an engineering staff that is constantly exploring new instrumentation concepts in the process and power field. Associate with a staff of instrument and control engineers, and data handling and computing experts.

We offer top salaries, suburban Chicago location, recognition of your achievements and other benefits. For interview send resume to Mr. W. A. Wecker, Personnel Director.

PANELLIT SERVICE CORPORATION

7401 N. Hamlin Avenue
Skokie, Illinois

ASSISTANT CHIEF ENGINEER

Fractional HP Motors Exp. Design & Dev. of Small Motors, Servos, Taco—Meters and Other Precision Electro Mechanical Devices for Military and Commercial Use. Leading to Position of Chief Engineer. Fast Expanding Concern. $12,000 to Start. No Fee.

MONARCH PERSONNEL
28 E. Jackson Blvd. Chicago, Ill.

SELLING OPPORTUNITY WANTED

British manufacturing company will act as agents or distributors of electrical timing and control equipment in England. Forward catalogues with price lists. Equipment and Services Limited, Harlow, Essex, England.

H HONEYWELL

baroswitch development engineer

Graduate mechanical engineer with 5 to 7 years' product design experience in the field of small mechanical or electro-mechanical devices. Minimum 3 years' experience in field of barometric switches. Will independently direct a baroswitch development program.

Please write F. W. Miller, Dept. 225, Honeywell, 2753 Fourth Ave. So., Mpls.

Honeywell
First in Controls

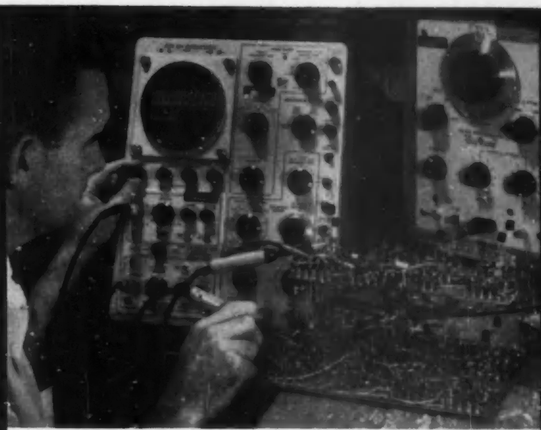
---

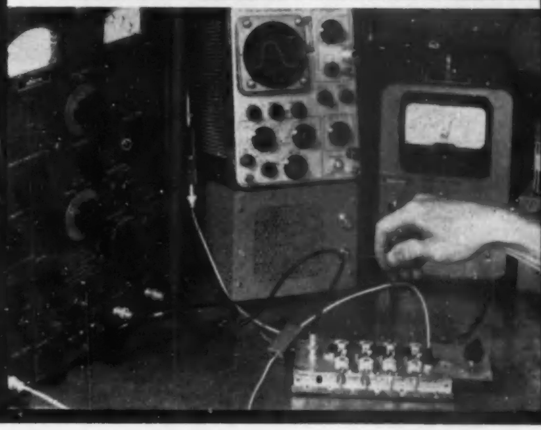
10 COMPONENT ENGINEERS
SALARY $14,000 PER YEAR

A leading prime contractor in electronics needs component engineers for electrical—electronic and mechanical devices such as transformers, tubes, gear trains, servo and synchro mechanisms. Company client will assume all employment expense.

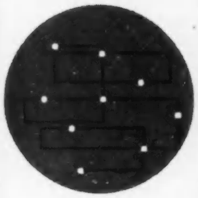
ESQUIRE PERSONNEL INC.
202 South State St., Chicago 4, Ill.

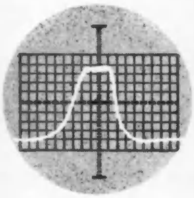
CAREER OPPORTUNITIES AT TI





CIRCUIT DEVELOPMENT ENGINEER





your future: a challenging opportunity with an industry leader

At Texas Instruments, your future is filled with specific, stimulating growth assignments in evaluating and characterizing transistors and special semiconductor devices. You'll participate in such transistorization projects as:

- **AM, FM, and TV receivers**
- **audio and video, i-f and r-f amplifiers**
- **hi-fi and electronic organs**
- **nonlinear and switching circuits**
- **computer system logic**
- **servo and power amplifiers**

With TI . . . receive liberal company-paid benefits, including profit sharing *(over last several years, an average of more than 12% of base salary)* . . . enjoy premium living in a moderate climate with excellent neighborhoods, schools and shopping facilities . . . work in a plant selected as one of the 10 outstanding U. S. industrial buildings of 1958.

Interviews will be held in your area soon. If you have an Electrical Engineering degree and/or knowledge of transistor circuitry, please send a resume to

C. A. Besio, Dept. 200-CE

TEXAS INSTRUMENTS
INCORPORATED
SEMICONDUCTOR – COMPONENTS DIVISION
POST OFFICE BOX 312 • DALLAS, TEXAS

For immediate Eastern appointment, contact
W. T. Hudson
Dept. 200-E-CE
1141 E. Jersey St.
Elizabeth, N. J.

ADVERTISERS IN THIS ISSUE

•

CLASSIFIED ADVERTISING
F. J. Eberle, Business Mgr.

District Managers

ATLANTA 3: R. H. Powell, 1301 Rhodes-Haverty Bldg., JAckson 3-6951
BOSTON 16: G. Stewart Baird Jr., 350 Park Square Bldg., HUbbard 2-7160
CHICAGO 11: Milton J. Steinbraker, 520 N. Michigan Ave., MOhawk 4-5800
CLEVELAND 13: John C. Mitchell, 55 Public Square, SUperior 1-7000
DALLAS 1: Gene Holland, Vaughn Bldg., 1712 Commerce St., RIverside 7-5117
DENVER 2: John W. Patten, Mile High Center, 1740 Broadway, ALpine 5-2981
LOS ANGELES 17: Gene A. Fruhling, 1125 W. Sixth St., HUntly 2-5450
NEW YORK 36: J. M. Morris, John B. Brennan, 500 Fifth Ave., OXford 5-5959
PHILADELPHIA 3: W. F. Buehl, Six Penn Center Plaza, LOcust 8-4330
SAN FRANCISCO 4: W. C. Woolston, 68 Post St., DOuglas 2-4600
LONDON E.C. 4, ENGLAND: E. E. Shirmer, 95 Farrington St.
FRANKFURT-MAIN, Germany: M. R. Zeynel, 85, Westendstrasse